NOLAN, DAVIS & ASSOCIATES

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THE HYDROLOGICAL STUDY OF A LARGE COAL STOCKPILE

(50/50 COST SHARING PROGRAM)

FINAL REPORT BY

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HYDROLOGY OF LARGE COAL STOCKPILES AT THE VICTORIA JUNCTION COAL PREPARATION PLANT

Project No. S89089

Submitted to:

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EXECUTIVE SUMMARY

The Cape Breton Development Corporation's (CBDC's) Victoria Junction Coal Preparation Plant (VJCPP) is located in Sydney, Nova Scotia. It produces metallurgical (Met) and Thermal grade coal from the high volatile A bituminous coal mined within the Sydney Coalfield.

Prior to transport by ship to overseas markets, the coal is temporarily stored above grade, and open to the weather for 30 days, to allow for methane degasification. However, such exposure increases the moisture content of the coal, due to infiltration of precipitation. This is of special significance since the site is positioned within one of the two highest zones of total annual precipitation in Canada (a 30 year Normal of 1400 mm per year). This is compounded by a localized, longterm trend of increasing precipitation; with an increase of 256 mm in annual precipitation since the late 1950's.

Increasing moisture content within the piles has ramifications for operations, including handling problems during the winter months due to freezing, and contract penalties if moisture specifications are exceeded.

As a result, CBDC and CANMET contracted Nolan, Davis & Associates to undertake an investigation into the hydrology of large, above-grade coal stockpiles to establish methods of minimizing moisture contents.

The field program associated with the study entailed the monitoring of four separate piles during the period from June 1989 to December 1990. Both years exhibited drier and hotter summers then normal. However, on an annual basis the long term trend of increasing total annual precipitation continued, due principally to increased fall rains.

The coal piles are constructed with rubber tyred coal haulers and dozers. The 10-12 m high, 60 m wide piles are therefore characterized by a compacted centre core running the entire 230-330 m length. The 35° side slopes are loose and uncompacted. The tonnage stored ranges from 30,000 to 130,000 tonnes.

During rainfall events the compacted core of the piles generate a relatively large amount of surface runoff. Lateral runoff toward the side slopes can result in infiltration into the loose, permeable, unsaturated zone. Runoff, diverted down the compacted centre to either end, creates large erosional gullies, which likely increase infiltration into the compacted core.

The saturated zone within the piles monitored was thin to non-existent. The maximum saturated zone monitored was less than 10 % of the total thickness of the pile and, where it discharged at the edge of the pile, it was only a few centimetres thick. Water table fluctuations did not closely correlate with rainfall events. Thermocouples indicated maximum core temperatures below 10 ^{0}C and except near the surface, changed very little over time. Diurnal variations were noted in seepages out the sides of the pile on hot summer days, implying the importance of evaporation losses directly from the saturated zone in proximity to the toe of the slopes.

Therefore, water movement in the saturated zone is felt to be the key to understanding and controlling moisture content within the piles. Recommendations are put forth to investigate infiltration within the unsaturated zone in more detail during the next phase of the study.

To aid in controlling moisture content within the piles, the data gathered to date indicates that the following practises would be beneficial:

1) construct the piles so as to achieve the maximum height over the smallest area, consistent with stable side slopes;
2) reduce incoming moisture content from the preparation plant to the maximum degree practical
3) enhance the percentage of surface runoff by:
   - compacting the surface using rubber tyred vehicles;
   - compacting the side slopes;
   - utilizing alternate ends of the pile for bringing loaded coal haulers onto the pile;
   - creating a more convex longitudinal profile, with no flat topped centre section;
   - creating a slightly concave cross sectional profile to direct runoff away from the side slopes;
   - fill in erosional gullies on either end of the pile as soon as possible;
   - lift the bank predominately from the base, and in as short a time frame as possible.

SOMMAIRE

L'usine de préparation du charbon de la Victoria Junction (UPCVJ), relevant de la Société de développement du Cap-Breton (SDCB), est située à Sydney, en Nouvelle-Écosse. On y produit de la houille métallurgique et de la houille thermique à partir du charbon bitumineux hautement volatil A que l'on exploite dans le bassin houiller de Sydney.

Avant son transport par navires-conteneurs vers les marchés d'outre-mer, on entrepose temporairement le charbon au-dessus de son niveau, à l'air libre pendant une trentaine de jours pour permettre l'évaporation du méthane. Cette exposition a cependant comme effet d'augmenter la teneur en humidité de la houille en raison de l'infiltration des eaux de pluie, facteur non négligeable car le site en question se trouve dans l'une des deux zones canadiennes avec les précipitations annuelles les plus élevées (moyenne annuelle sur 30 années: 1400 mm). À ceci s'ajoute une tendance locale, à long terme, de précipitations annuelles plus abondantes depuis la fin des années cinquante, avec une augmentation de 256 mm.

L'augmentation du taux d'humidité à l'intérieur des piles de charbon entraîne des conséquences pour l'exploitation, notamment des problèmes de manutention pendant l'hiver à cause du gel, et des pénalités lorsque l'humidité excède les spécifications contractuelles.

La SDCB et CANMET ont donc chargé Nolan, Davis & Associés d'entreprendre une étude sur l'hydrologie des grandes masses de charbon exposées au jour, afin de découvrir des moyens de réduire au maximum les taux d'humidité.

L'étude comprenait un programme d'observation sur place de quatre différentes piles entre juin 1989 et décembre 1990. Au cours de ces deux années, les étés furent plus chauds et secs que d'habitude. Au total toutefois, la tendance à des précipitations annuelles à la hausse s'est maintenue, surtout à cause de pluies d'automne plus abondantes.

Les piles de charbon sont érigées par des bulldozers et des camions à pneus en caoutchouc. Hautes de 10-12 m et larges de 60 m, elles se caractérisent par un noyau central rendu compact et s'étendant sur toute la longueur, c'est-à-dire sur 230-330 m. Les côtés, en pente de 35°, ne sont pas comprimés. Le tonnage de houille entreposée varie entre 30 000 et 130 000 tonnes.

Au cours des précipitations, le noyau compact des piles produit un suintement de surface en quantité appréciable. Le ruissellement vers les pentes

latérales peut résulter en une infiltration à même la zone non compacte, perméable et non saturée. Dispersé depuis le centre compact vers les extrémités, il en résulte la formation de grandes rigoles érosives qui, tout probablement, contribuent à augmenter l'infiltration vers le centre comprimé.

Selon nos observations, la section saturée à l'intérieur des piles examinées était mince ou inexistante. La section saturée la plus importante que nous ayons remarquée représentait moins de 10% de l'épaisseur totale de la pile et, en périphérie, n'avait que quelques centimètres d'épaisseur. Les fluctuations du niveau d'eau répertoriées correspondaient d'assez loin aux précipitations. Les thermocouples indiquaient pour le noyau des températures maximales en deçà de 10°C, qui restèrent à peu près inchangées au cours de la période, sauf près de la surface. Les variations diurnes se manifestèrent pendant les chaudes journées d'été par des suintements vers l'extérieur des côtés; on peut en déduire l'importance des pertes par évaporation, directement à partir de la section saturée au pied des pentes.

Le mouvement des eaux dans la zone saturée fournit donc, selon nous, des éléments-clés pour comprendre le phénomène et exercer un contrôle sur la teneur en humidité des piles. Des recommandations quant à l'examen plus détaillé de l'infiltration suivent à la prochaine étape de l'étude.

Les données recueillies jusqu'à présent justifieraient l'adoption des mesures suivantes afin d'aider au contrôle de l'humidité à l'intérieur des piles:

1) la construction de piles à hauteur maximale par rapport à leur surface, tout en veillant à la stabilité des pentes;
2) une réduction optimale du niveau d'humidité à partir de l'usine de préparation;
3) une augmentation du pourcentage d'écoulement en surface, soit:
   - en pressant la surface sous des véhicules munis de pneus de caoutchouc;
   - en comprimant les pentes latérales;
   - en utilisant à tour de rôle les extrémités des piles pour l'acheminement des camions chargés;
   - en créant un tracé longitudinal plus convexe, sans plateau central;
   - en créant une coupe transversale légèrement concave, afin de faire dévier les écoulements des pentes latérales;
   - de remplir au plus tôt les ravins à chacune des extrémités des piles;
   - en déchargeant principalement à partir de la base et dans les plus brefs délais possible.

CONCLUSIONS

1) The positioning of CBDC's facilities within the eastern sector of the Maritime Provinces places it within one of the two highest zones of total annual precipitation in Canada, with a 30 year Normal of 1400 mm. This is compounded by a long term trend of increasing precipitation, resulting in an increase of 256 mm, since the late 1950s; felt predominately during the fall rains. Superimposed upon this trend were two dry summers during the study period (1989 and 1990), due to reduced rainfall and warmer than normal temperatures in July and August of each year.

2) The present methods of constructing the large coal piles, utilizes rubber tyred coal haulers and dozers. The piles are therefore characterized by a compacted centre core running the entire length of the pile; the 35^0 side slopes are loose and uncompacted. The compacted core exhibits hydraulic conductivities in the order of 10^{-6} cm/sec..

3) The compacted core of the piles generates a relatively large amount of surface runoff. Lateral runoff toward the side slopes can result in one of three processes, namely: A) infiltration into the loose unsaturated zone, B) development of gullies in the side slopes if the flow was concentrated prior to reaching the edge, and C) the creation of "quick" conditions in the upper few centimetres, resulting in the development of translational slips and resultant rill development.

   The portion of the runoff diverted down the compacted centre portion of the pile to either end creates large erosional gullies. Development of these features is expected to hasten infiltration.

4) The saturated zone within the piles monitored was thin to non-existent. The maximum saturated zone monitored was less than 10% of the total thickness of the pile within the core; at the sides of the pile it was only a few centimetres thick. Therefore, water movement in the unsaturated zone is the key to understanding and controlling moisture content within the piles.

   The average moisture contents in the unsaturated zone ranged from 6 - 10%. Field moisture capacity is unknown; but was theoretically calculated to be in the 10 - 20% range. If correct, this implies that gravity drainage does not occur within the pile, except perhaps in isolated areas where runoff is concentrated i.e. in gullies.

   Thermocouples indicated core temperatures were not sufficient enough to evaporate the moisture within the unsaturated zone.

Given that the gas pressure/composition in the unsaturated zone was not monitored, the role played by methane degasification in controlling infiltration is not known.

5) The saturated zone within the piles appears to be thin to non-existent. As well, the data implies that it may not be continuous throughout the pile. There was no indication of perched water tables within the pile. All seepage out of the pile was noted from the toe of the side slopes.

The areas of toe seepage were sporadic and did not correlate with the zone of maximum saturated zone thickness, as determined from the piezometers. This may be a function of the higher water levels being associated with denser, lower permeable material; the latter resulting in a reduction in the rate of lateral flow out of the pile.

Water table fluctuations did not closely correlate with rainfall events.

Diurnal variations were noted in seepages out of the sides of the pile on hot summer days, implying the importance of evaporation losses directly from the saturated zone along the side slopes.

6) Recommendations were outlined to aid in controlling moisture content with the piles. These included:

A) The volume of precipitation landing on the pile should be reduced by constructing the piles to achieve the maximum heights possible over the smallest area. In addition, the piles should be constructed and removed as quickly as possible. The implementation of these methods should be considered to be more imperative in the late fall and winter months.

B) Incoming moisture contents, created by the preparation process, should be reduced to the minimal level which is practically achievable.

c) The volume of surface runoff should be enhanced by the following operational procedures, where practical:

- compacting the surface through the use of rubber tyred vehicles
- rolling the side slopes
- utilizing alternate ends of the pile for bringing loaded coal haulers onto the pile
- creating a more convex longitudinal profile with no flat topped centre section
- creating a slightly concave cross sectional profile to direct surface runoff away from the less compacted side slopes
- fill in erosional gullies on either end of the pile as soon as possible
- "lift" the bank predominately from the base, not the top.

7) One of the main methods for controlling moisture in the pile will deal with how the unsaturated zone is manipulated. This will necessitate how to achieve the proper combination of grain size, porosity, permeability and field moisture capacity, in order that infiltrating water is allowed to quickly move vertically to the saturated zone, and then discharged out of the pile. However, this requirement must be balanced against creating to permeable a structure, which would allow diffusion of oxygen into the pile; with the resultant reduction in fluidity of the coal, and the enhancement of acidic drainage. To determine the optimum balance will require detailed study o the unsaturated zone; and is therefore the subject of the recommendations put forth for future work.

RECOMMENDATIONS

A follow-up phase of work is recommended; the design for which is presented below for consideration. The work program keys in on obtaining a better understanding of infiltration rates/volumes and the fate of water in the unsaturated zone. The program should include:

1) Infiltration studies should be carried out over the surface of the pile to quantify infiltration capacity (F) for the three classes of surface cover noted. This should also include assessing the decrease in F by varying operational methods, including but not limited to: A) number of passes with loaded and unloaded coal haulers, rubber tyred dozers and rollers B) rolling the side slopes, and C) application of binders, sealants, etc. This should also include lab scale testing to determine the relationship between size distribution, compaction pressure, and infiltration rate/ field capacity.

2) It will be necessary to quantify percent moisture at saturation and field moisture capacity for the range of densities found within the pile. This could be carried out at the laboratory and/or rail car experimental cell, type scale of investigation.

3) The unsaturated zone of operational piles should be instrumented to quantify: temperature, moisture, gas pressure/composition, and water chemistry.
This program should be augmented with A) piezometers in the saturated zone at an enhanced "level-of-effort"(to determine the continuity of the saturated zone throughout the pile), as well as water sampling to determine chemistry, and B) more detailed sampling by CBDC on grain size, moisture, ash, sulphur contents and tonnages on the incoming coal as well as grain size, moisture on lifted coal and detailed surveying of the piles.

4) The above data should be utilized in conjunction with additional lab testing to determined how long it would take for moisture brought in with the coal to decrease to its minimum value if the piles were covered with some form of liner.

5) Given this level-of-effort, it would be preferable to attempt a water balance for the piles. However, this would require monitoring surface water runoff and groundwater discharge. The required instrumentation is not practically feasible for operational piles.

6) Two dimensional computer modelling of the saturated and unsaturated zones should be given consideration. As well it would be used to assess the impact of various designs of coarse and fine coal layers within the pile on altering runoff and moisture contents.

Other issues that should be considered include:

1) The cost/benefit of covering the piles with some type of removable sheeting which would keep rain out, yet still allow degassing, could be investigated.

2) Discussions should be held with the pertinent regulatory agencies to determine the validity of a 30 day period as an acceptable level of degassing.
The cost/benefits of incorporating a man-induced enhancement of degassing through some form of vacuum extraction could be investigated.

1.0 INTRODUCTION

1.1 Background

The Cape Breton Development Corporation's (CBDC) Victoria Junction Coal Preparation Plant (VJCPP) was constructed in 1976 near Sydney, Cape Breton, Nova Scotia (Figure 1-1). The plant was enlarged in 1987 to a rated capacity of 860 tonnes per hour. It employs heavy medium cyclones, water only cyclones and froth flotation to reduce the ash and sulphur content of the high volatile A bituminous coal mined within the Sydney coalfield. Specifically, the plant is located some 6 km east of Sydney on the eastern shoreline of Grand Lake (Figure 1-2).

All of the metallurgical (Met) grade coal is transported to overseas markets by ship. Prior to shiploading, the Department of Transportation regulations require that the coal be left exposed for 30 days to allow for methane degassification, in order to reduce the risk of explosion in transit. Therefore the coal is stockpiled in an area open to the weather.

Initially the coal was placed upon natural ground surface during the temporary storage period. In 1983 a Lifting Banking Centre (LBC) was constructed (Figure 1-3) for the temporary above grade, uncovered storage of both Met and Thermal grade coal (Plates 1 & 2). This site employs an at-grade asphalt base under the storage area. After storage, the coal is transported to local markets or to ship load out facilities by unit trains.

However such exposure increases the ability for rainfall to enter the pile and increase moisture contents; which is enhanced by precipitation received during stockpile recovery and shiploading. This is of special significance, since the site is located in one of

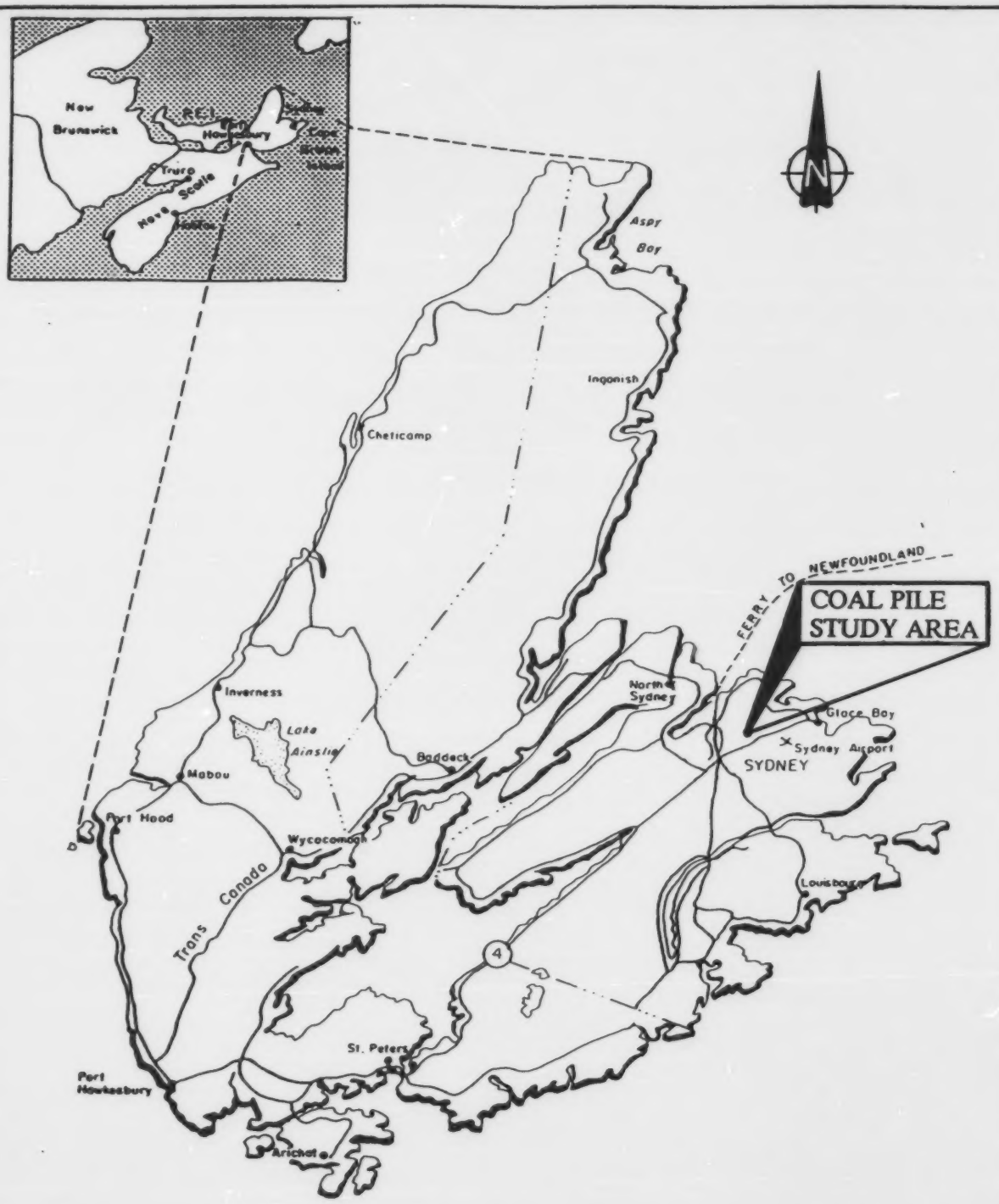

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FIGURE 1-1
REGIONAL LOCATION PLAN
CAPE BRETON ISLAND

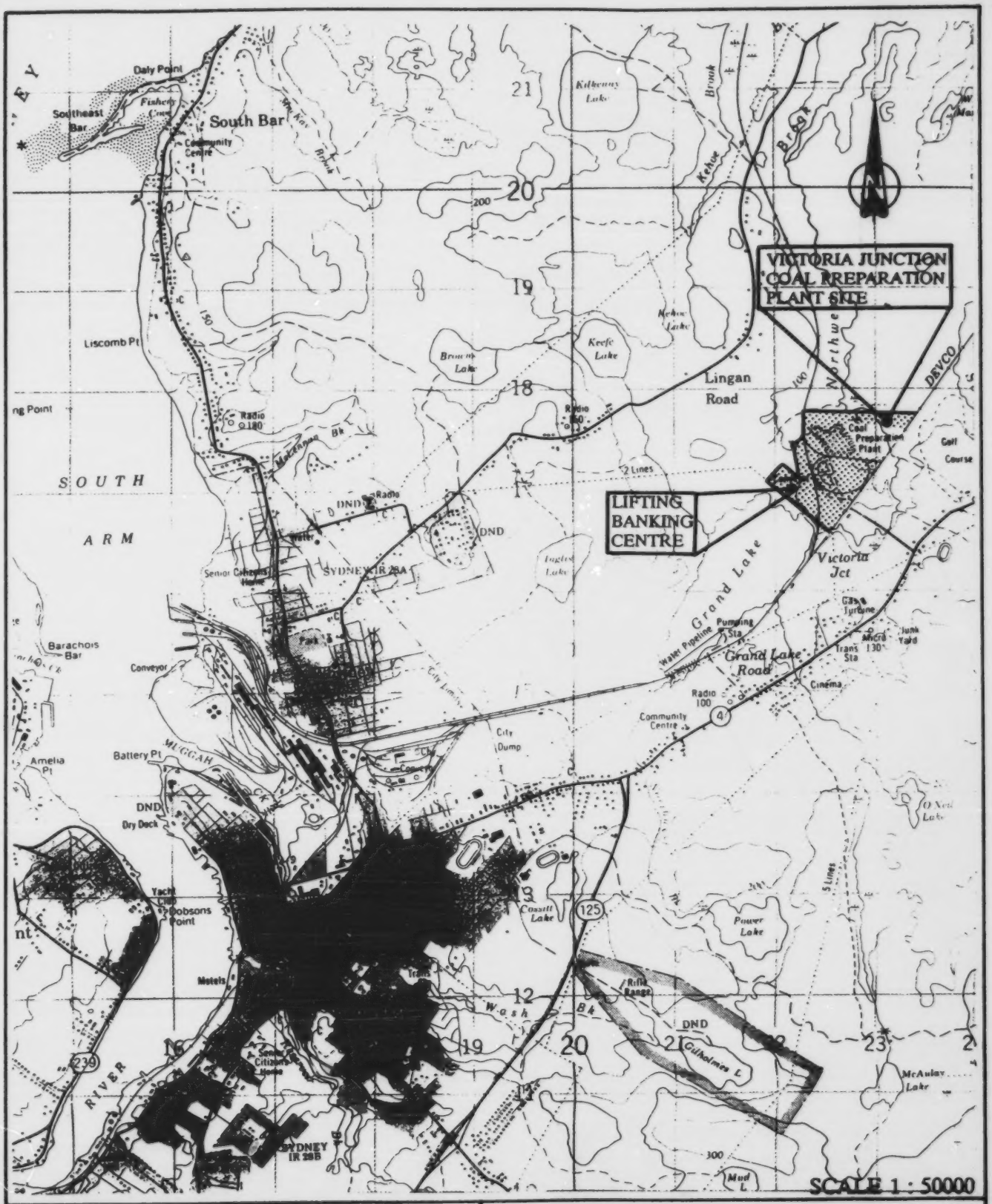

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FIGURE 1-2
LOCATION MAP

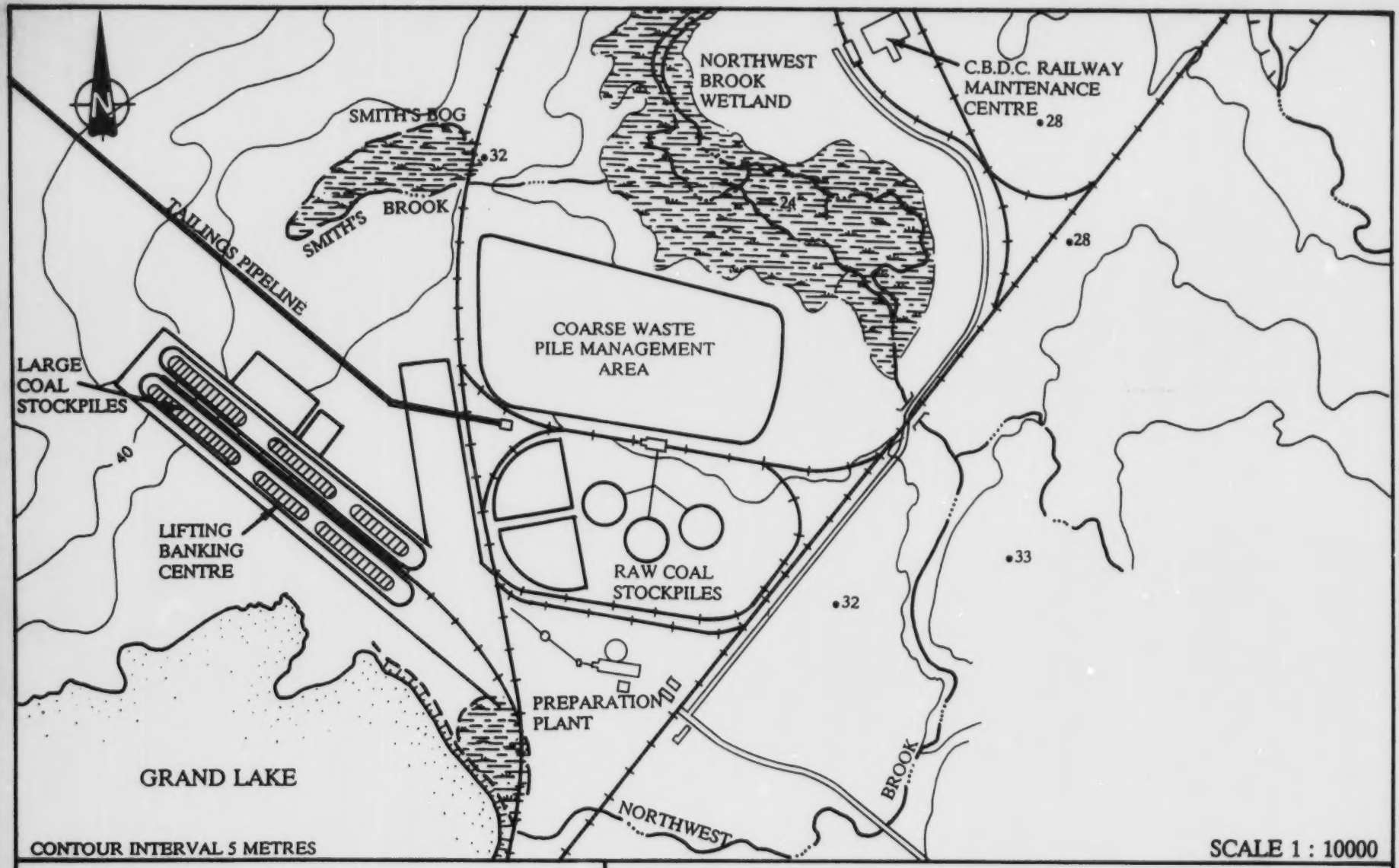

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FIGURE 1-3
SITE LOCATION PLAN
FOR THE VICTORIA JUNCTION COAL
PREPARATION PLANT

the two highest rainfall regions in Canada (greater than 1000 mm total annual precipitation). Further, the local climate station is recording a long term trend of increasing total annual precipitation since the mid 1950s.

Increasing moisture content within the pile has three serious ramifications for operations, including:

A) Penalties must be paid by CBDC if the moisture content in the coal exceeds a specific value written into the individual contracts; usually in the range of 8 - 9%. Therefore moisture contents must be kept to less than this specified range.

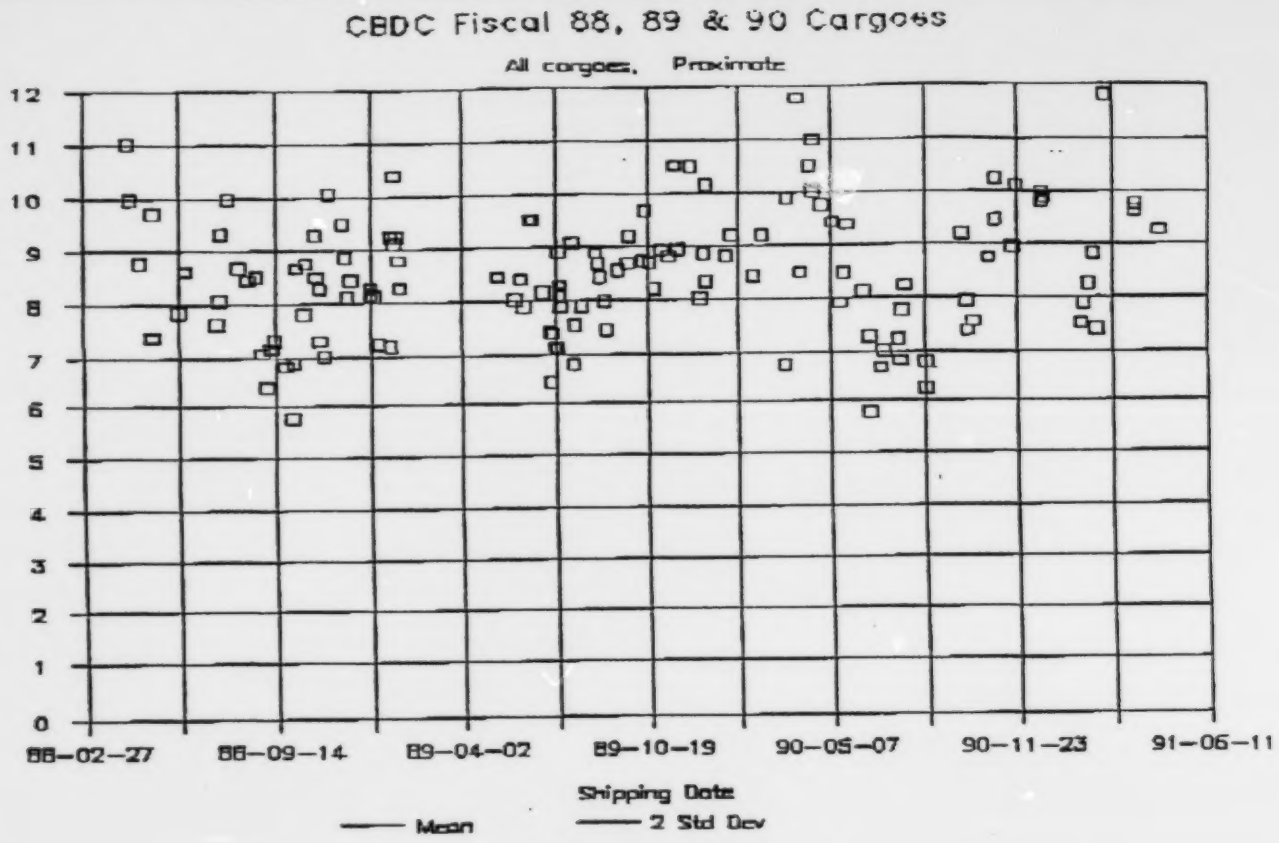
B) Moisture in coal near the surface of the pile can freeze and create operational problems in removing and transporting the coal by rail from the LBC to the vessel load out terminal. Similar problems can result with handling of high moistures in unfrozen coal during freezing weather conditions.

C) The chemistry and volume of potentially acidic leachate discharging off the pile by surface and/or groundwater, and the resulting environmental risks, are a function of moisture movement through the pile.

In 1987 a distinct seasonal variation in the moisture content of the stockpiled coal was noticed, with variations ranging from 5% in the summer, to 10% in the late fall, winter, and early spring. The data for moisture contents of coal being placed on-board ship for the period 1988, 89 and 90 support this contention, as shown on Figure 1-4.

1.2 Terms of Reference

As a result of the moisture problems, CBDC and the Canada Centre for Mineral and Energy Technology (CANMET) contracted Nolan, Davis and Associates (N.S.) Ltd (Nolan Davis) in February 1989 to undertake an investigation into the hydrology of the above-grade coal stockpiles at the LBC.



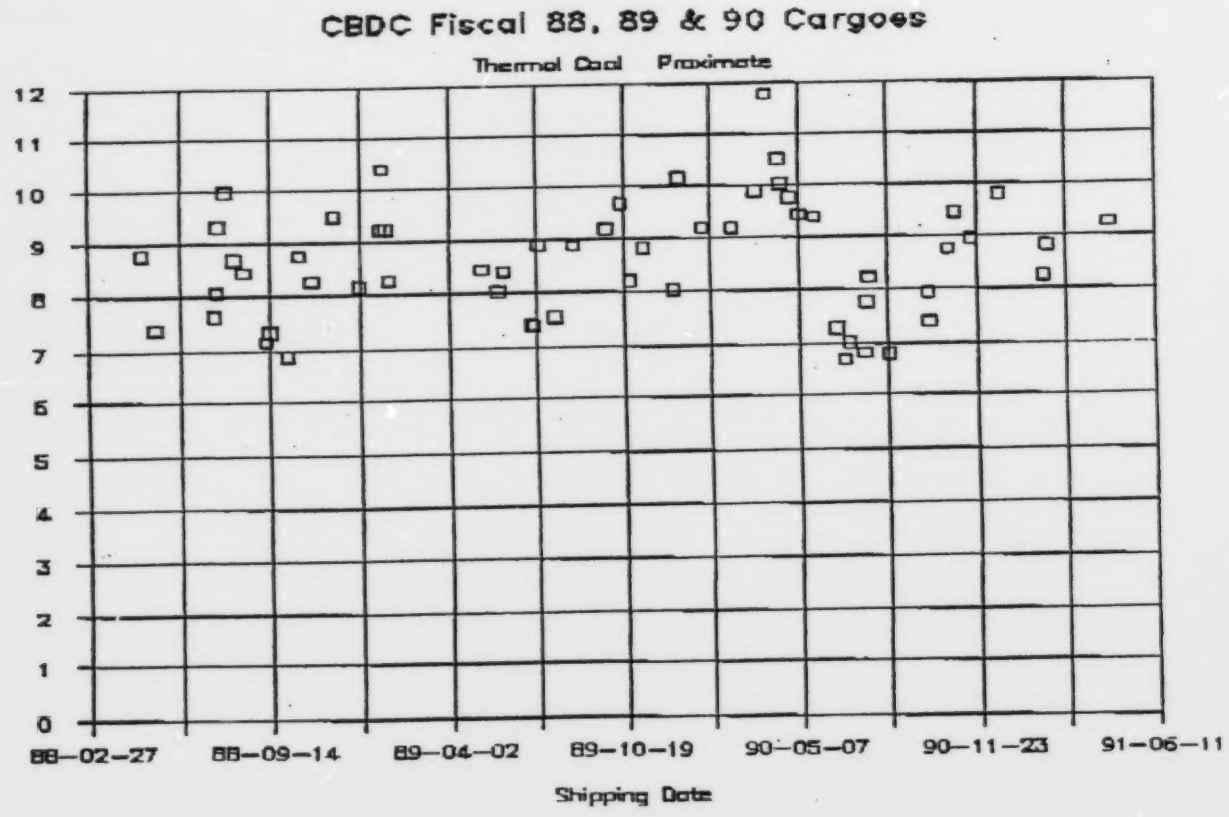


FIGURE 1-4 MOISTURE CONTENT OF CARGOES SHIPPED BY VESSEL FOR THE PERIOD 1988-90 INCLUSIVE
(COURTESY OF J.C. CAMPBELL, CBDC)

The prime goal was to assess the climatic and hydrological factors which affect the moisture content of the stockpiles. It was also intended to establish whether an empirical relationship exists between climatic/hydrological parameters and the coal stockpile moisture content.

The program was to key in on the physical components of the hydrologic cycle within the piles, not the water chemistry.

1.3 Philosophy of Approach

The approach taken to assess the problem incorporated the following major design parameters:

1) It was decided to monitor operational piles rather than attempt to create a small experimental pile. This was necessitated by: a) the problems in finding room for such a pile at the LBC, b) the difficulties in building a small pile in the same manner used for the operational piles, and c) the viability of extrapolating conditions from a small to a larger pile.

   To construct one pile of normal operational dimensions for monitoring was not considered to be economically viable. This created difficulties in trying to blend the need for monitoring with day-to-day operations.

2) To assess the full range in hydrological conditions, monitoring was carried out over all climatic variations expected within the Maritime climate through one "water year". The frequency of monitoring at this stage of investigation was considered to be sufficient to identify seasonal variations. The one month time frame, over which the piles are exposed necessitated monitoring four different piles; one for each season.

3) Three "levels - of - effort" were presented to the overview committee in terms of instrumentation to be installed. Given the minimal amount of data in the North American literature on hydrology of large coal stockpiles, and the

budgetary limitations, it was decided that this study should focus in on monitoring only the saturated zone within the pile; neither the unsaturated zone nor surface runoff was targeted for detailed quantitative analysis.

4) The combination of instrumentation and field inspections was utilized to develop a conceptual/analytical model of the hydrologic cycle for the piles; numerical modelling was not employed.

1.4 Field Program

The field program took place between June 1989 and December 1990. During that time interval four piles were monitored as summarized in Table 1-1.

TABLE 1-1

DURATION/TIMING OF COAL PILES BEING MONITORED

- PILE 1 - No 65 Thermal Bank ; June to September 1989 (representing summer conditions)
- PILE 2 - No. 74 Met. Bank; October and November 1989 (representing fall conditions)
- PILE 3 - No. 77 Met. Bank; March 1990 (representing winter/spring conditions)
- PILE 4 - No. 74 Met. Bank; July to December 1990 (representing summer/fall conditions)

Pertinent field components included:

A) Augering/Piezometer Emplacement

Each pile was augered to the base of the pile in at least five pre-selected locations to obtain: continuous split spoon samples, relative density (N) values, and to allow for installation of piezometers. Augering was accomplished utilizing hollow stem augers on a CME 55 supplied by Longyear Drilling Inc. Care was taken not to break through the asphalt pad which acted as an aquitard under the site.

The same positioning of piezometers was used for each pile, encompassing three sites at the centre point of the pile to give a transverse cross section i.e. one in the middle and one as close to either edge as possible (Plate 5). This was augmented by two additional piezometers located near either end of the pile along the mid line, in order to develop a longitudinal profile. This core program was augmented by piezometers along the toe of the side slopes, when considered necessary.

Given that acquisition of chemistry data was not critical, and that the piezometers were expected to be destroyed during removal of each pile, they were constructed of 5.1 cm ID ABS plastic pipe with glued couplings. The 0.76 m screened interval was wrapped with nylon fabric. To maintain coal quality control neither a sand pack nor a bentonite seal could be utilized. The annular space was therefore backfilled and compacted as much as possible with coal particles removed during augering.

On two piles thermocouples were attached to selected piezometers to quantify temperature gradients within the pile.

B) Water Level Monitoring

Groundwater level monitoring was carried out by CBDC personnel on a daily basis whenever possible. This frequency was increased during selected rainfall events.

C) Surveying

Surveying of the final pile configuration and ground surface at piezometer installations was carried out by CBDC staff on selected piles.

D) Tonnage and Infeed Sampling

The monitoring of infeed tonnages to each pile, and collection of samples for analyzing moisture contents, sulphur and ash percentages as well as grain size was undertaken by CBDC personnel.

E) Laboratory Analysis

Laboratory analyses for the above parameters were carried out by the CBDC lab at the VJCPP. Water chemical analyses were carried out by the Environmental Chemistry lab of the Victoria General Hospital, Halifax, N.S.

F) Site Inspections

Site Inspections were carried out by Nolan Davis staff during pile construction, the monitoring period and during pile removal. The inspections were set up to obtain an understanding of operations, and the reaction of the piles to varying weather conditions.

G) Weather/Climate Data

Weather data was abstracted from the continuously manned Environment Canada Atmospheric Environment Service weather station at the Sydney Airport, located some 5.5 km to the east of the site.

A further discussion of data collection is provided in Section 4.0. Raw data is appended in Appendices 2 - 5 inclusive.

1.5 Report Format

Given the complexity of the study and the funding available, the reporting format included a progress report to be presented at the termination of the monitoring of Pile 2. This was to allow for the determination of whether the level-of-effort was sufficient to obtain enough practical information, and to finalize any changes to be made to the method of monitoring the last two piles. The report was submitted for review on January 22, 1990. It was decided to continue the program at a similar level-of-effort; supplemented with the addition of thermocouples at selected sites.

This report is the final report on the program. It is set up as follows:

Section 1: Discusses the background, overall approach to the program design, and a summary of the resultant field program employed.

Section 2: The hydrometeorlogical characteristics of the study period are discussed and compared with long term averages, in order to define the major climatic inputs and losses of moisture relevant to the piles.

Section 3: This section outlines the pertinent operational procedures utilized in constructing the piles.

Section 4: The resultant data collected on each pile is summarized. The raw data is presented in relevant appendices.

Section 5: The data and observations of all the piles are brought together to derive a conceptual/analytical model for the hydrology of the coal piles.

Section 6: A discussion of potential operational procedures which could be employed to minimize moisture within the piles is presented, based upon the data and observations made of the four piles under study.

1.6 Acknowledgements

Nolan Davis would like to acknowledge the assistance provide by Mr. J.C. Campbell of CBDC in providing expertise on coal properties, handling practices/problems, as well as critically reviewing the document.

Dr. T. Aston of CANMET provided assistance during the design phase of the study; Mr. G. Bonnell aided in the review of the document.

Appreciation is also extended to Mrs. D. Johnson and Mr G. Shaw of CBDC, who were responsible for data collection after the monitoring program was installed.

2.0 HYDROMETEOROLOGY

2.1 Introduction

Hydrometeorlogical conditions which affect the interpretation of the physical characteristics of the ground/surface water flow systems under investigation, include: A) the weather conditions during the monitoring period for each pile, B) the long term climatic conditions, and c) water budget analysis for the water years in which the piles were monitored.

Weather conditions during operational monitoring for each pile are discussed in Section 4.0 and relevant appendices. This section discusses factors B) and C) noted above.

2.2 Climatic Conditions

Relevant weather and climate data for the site was abstracted from the 49 years of continuous data collected at the Atmospheric Environment Service's (AES) climate station SYDNEY A, located at the Sydney Airport, some 5.5 km due east of the LBC. Its proximity and similar surrounding topography/ elevation is expected to provide acceptable accuracy in extrapolating conditions to the study area.

The long term climatic average conditions are delineated by the 1951 - 80 Normal period, and are summarized in Table 2-1. Briefly the data indicates a total annual precipitation of 1,399.9 mm, which is generally well distributed seasonally; but with maximum precipitation during the fall. The mean annual air temperature is 5.7^{0}C, with mean monthly values below freezing from December through March inclusive. Seasonal, mean monthly temperatures range from -5.9^{0}C in February, to 17.7^{0}C in July and August. This range is relatively small, being representative of coastline stations subjected to oceanic moderation.

TABLE 2-1

1951 - 1980 CLIMATIC NORMALS

AT SYDNEY AIRPORT

SYDNEY A 46° 10'N 60° 3'W 62 m	J	F	M	A	M	J	J	A	S	O	N	D	Annual		
Daily Maximum Temperature	-0.8	-1.6	1.4	6.0	12.5	18.9	23.1	22.6	18.5	12.7	7.3	1.7	10.2	1	Température Maximale Quotidienne
Daily Minimum Temperature	-6.5	-10.1	-6.3	-2.1	2.3	7.5	12.3	12.6	8.5	4.1	0.3	-5.2	1.3	1	Température Minimale Quotidienne
Daily Temperature	-4.7	-5.9	-2.5	2.0	7.4	13.2	17.7	17.6	13.5	8.4	3.8	-1.8	5.7	1	Température Quotidienne
Standard Deviation, Daily Temperature	2.3	2.6	1.5	1.4	1.4	1.2	1.5	1.1	1.2	1.0	1.5	2.1	0.8	1	Écart Type de la Température Quotidienne
Extreme Maximum Temperature	14.4	12.8	17.8	27.2	31.1	34.4	33.9	35.0	32.2	25.0	22.2	16.7	35.0		Température Maximale Extrême
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40			Années de Relèves
Extreme Minimum Temperature	-23.3	-25.6	-23.9	-13.3	-7.8	-3.9	2.2	2.8	-1.7	-5.6	-11.1	-18.9	-25.6		Température Minimale Extrême
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40			Années de Relèves
Rainfall	76.0	57.0	66.6	74.5	89.4	82.0	81.4	101.3	87.2	120.0	148.1	99.0	1062.5	1	Chutes de Pluie
Snowfall	74.5	66.6	63.9	25.4	5.3	T	0.0	0.0	T	2.6	12.0	65.6	317.9	1	Chutes de Neige
Total Precipitation	149.0	123.6	131.4	102.0	95.2	82.1	81.4	101.3	87.2	122.7	160.4	163.6	1399.9	1	Précipitations Totales
Standard Deviation, Total Precipitation	49.7	41.3	42.3	40.7	45.5	41.4	42.5	47.2	37.8	52.1	67.1	50.1	143.7	1	Écart Type des Précipitations Totales
Greatest Rainfall in 24 hours	57.2	58.4	52.6	56.1	93.5	72.1	63.8	62.2	90.9	58.9	97.3	94.0	97.3		Chute de Pluie Record en 24 heures
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40			Années de Relèves
Greatest Snowfall in 24 hours	44.5	45.2	37.3	29.2	24.9	1.0	0.0	0.0	T	15.7	21.6	58.7	58.7		Chute de Neige Record en 24 heures
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40			Années de Relèves
Greatest Precipitation in 24 hours	57.2	58.7	67.1	56.1	93.5	72.1	63.8	62.2	90.9	58.9	97.3	95.0	97.3		Précipitation Record en 24 heures
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40			Années de Relèves
Days with Rain	8	6	8	10	13	13	12	13	12	14	15	11	135	1	Jours de Pluie
Days with Snow	16	14	13	7	1	*	0	0	0	1	5	16	73	1	Jours de Neige
Days with Precipitation	20	16	17	14	14	13	12	13	12	15	18	22	166	1	Jours de Précipitation

Climatic analyses, utilizing running decadal means, indicated that there is a significant long term trend of increasing precipitation (Figure 2-1), commencing in the late 1950s and continuing through to the present day. This includes the 10 year period encompassed by 1990. The last 10 year mean records a value of 1548.8 mm, compared to 1323.3 mm for the 1955 to 1964 period; an increase of 225.5 mm. Analysis on a monthly level (utilizing data up to 1985) indicates that the increase is occurring in order of priority within the months of December, October and November. These months exhibit correlation coefficients with the annual trend of 0.93, 0.84 and 0.82 respectively.

Utilizing the same statistical technique, mean annual air temperature (Figure 2-2) over the same period of record indicated a decline commencing in the mid 1950s, from approximately 6.3^{0}C to a low of 5.3^{0}C in the mid 1970s. At that point the trend reversed itself with a rise, and then stabilized around the 5.6^{0}C mark.

Therefore, there are "moving" baselines present in pertinent climatic data, making it more difficult to make statistical comparison of the study years with "Normal" 30 year conditions. It was therefore decided that, in order to assess surface and groundwater conditions within the study period, it should also be compared to the last 10 year period (1980-1989 inclusive).

The total annual precipitation in 1989 (1247.0 mm) was below both the 30 year Normal, and 10 year mean by greater than 1 standard deviation (SD). The year 1990 (1666.8 mm) was higher than the 30 year Normal by greater than 1 SD, but was within 1 SD but above the 10 year mean.

It is of interest for this study however that the summer months in both years indicated lower than average rainfall. The rainfall received in July (42.7 mm in 1989 and 48.4 mm in 1990), and August (61.2 mm in 1989 and 62.5 mm in 1990) were nearly

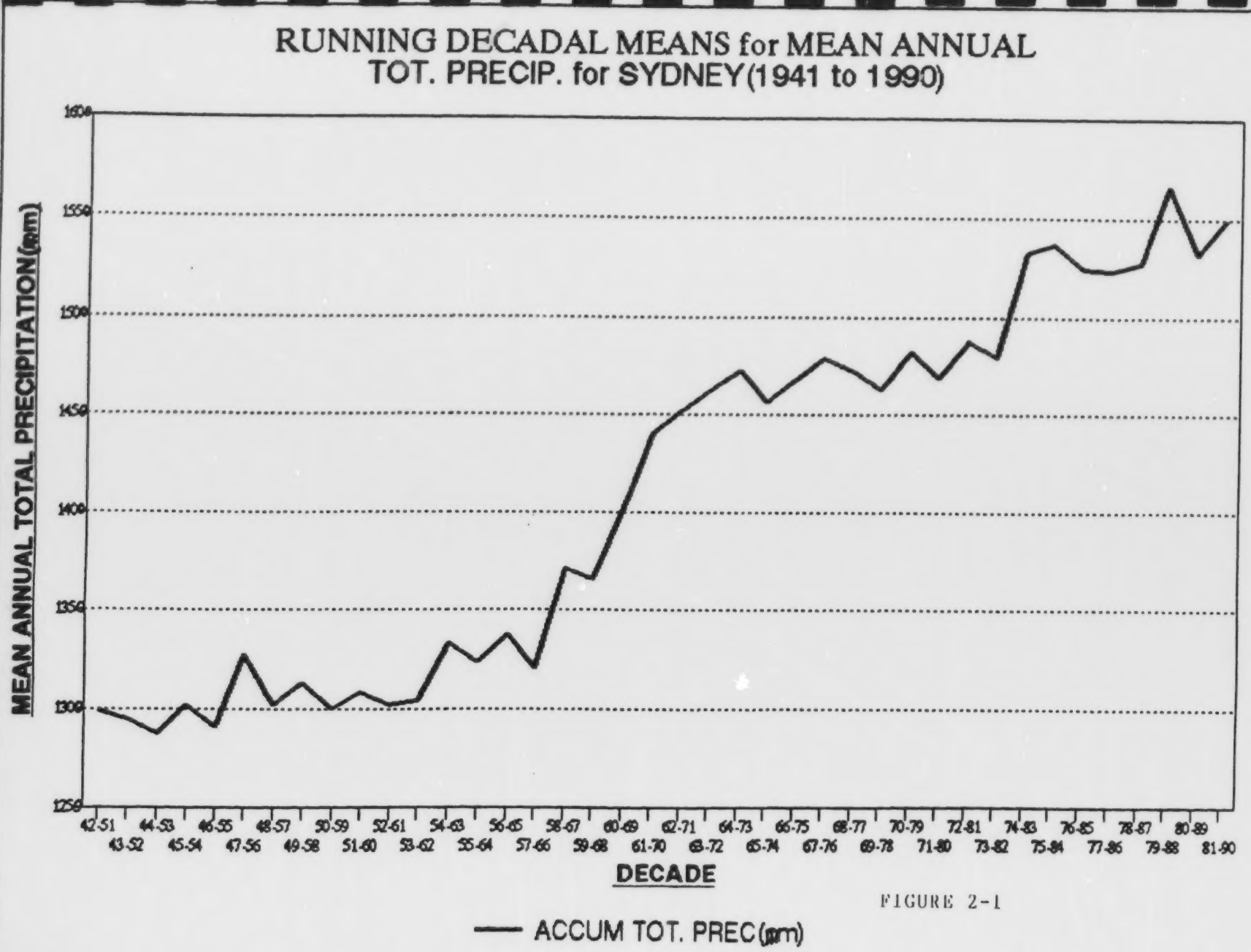

RUNNING DECADAL MEANS for MEAN ANNUAL
TOT. PRECIP. for SYDNEY(1941 to 1990)
MEAN ANNUAL TOTAL PRECIPITATION(mm)
1600
1550
1500
1450
1400
1350
1300
1250
42-51
43-52
44-53
45-54
46-55
47-56
48-57
49-58
50-59
51-60
52-61
53-62
54-63
55-64
56-65
57-66
58-67
59-68
60-69
61-70
62-71
63-72
64-73
65-74
66-75
67-76
68-77
69-78
70-79
71-80
72-81
73-82
74-83
75-84
76-85
77-86
78-87
79-88
80-89
81-90
DECADE
ACCUM TOT. PREC(mm)

FIGURE 2-1

RUNNING DECADAL MEANS for MEAN ANNUAL AIR TEMP. for SYDNEY (1941 to 1990)

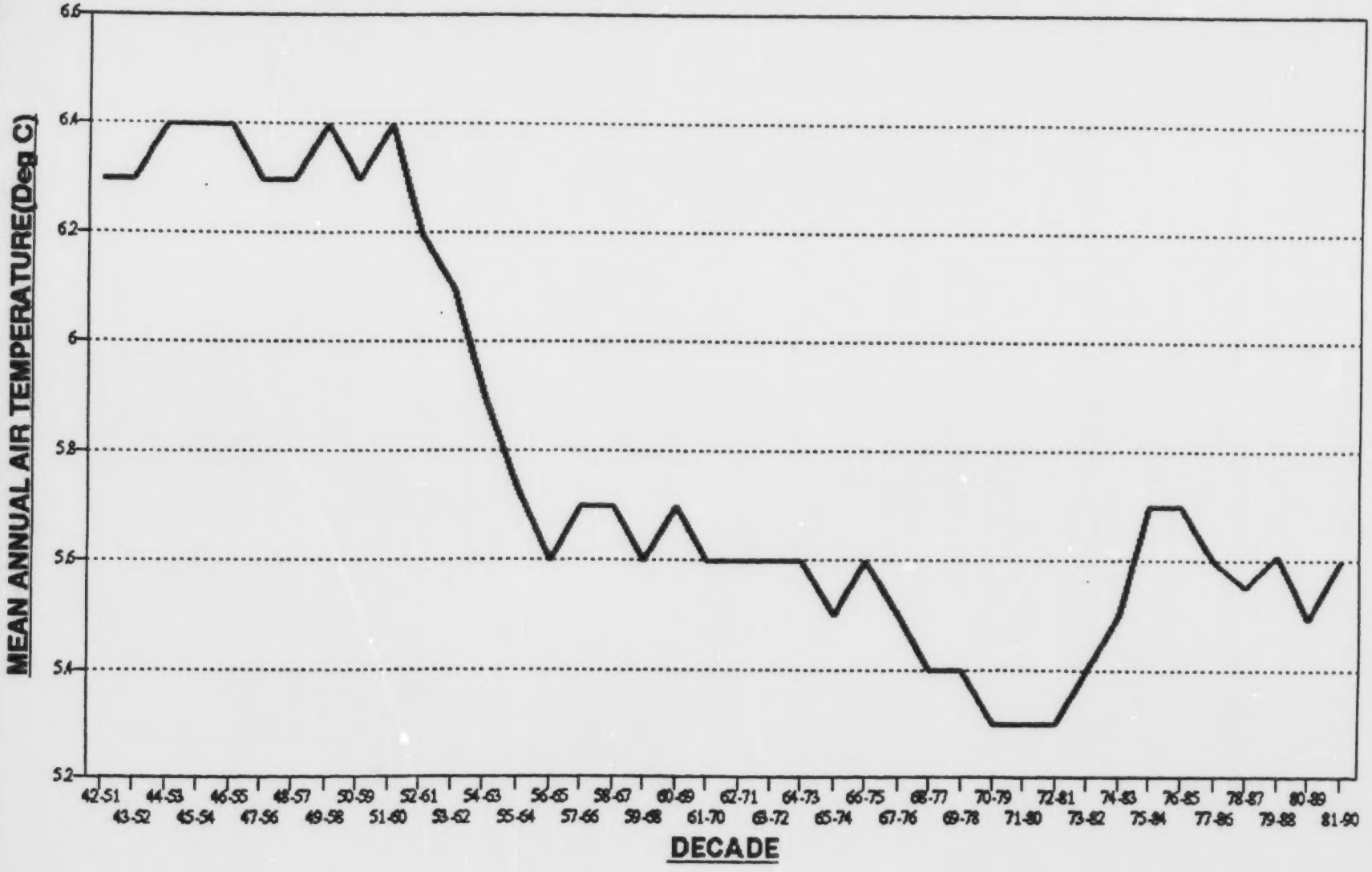


FIGURE 2-2

identical. The July values were lower than both the 30 year Normal and 10 year mean but did not quite exceed 1 SD. The August values were lower than the 30 year Normal but did not quite exceed 1 SD; they were however lower than the 10 year mean by more than 1 SD.

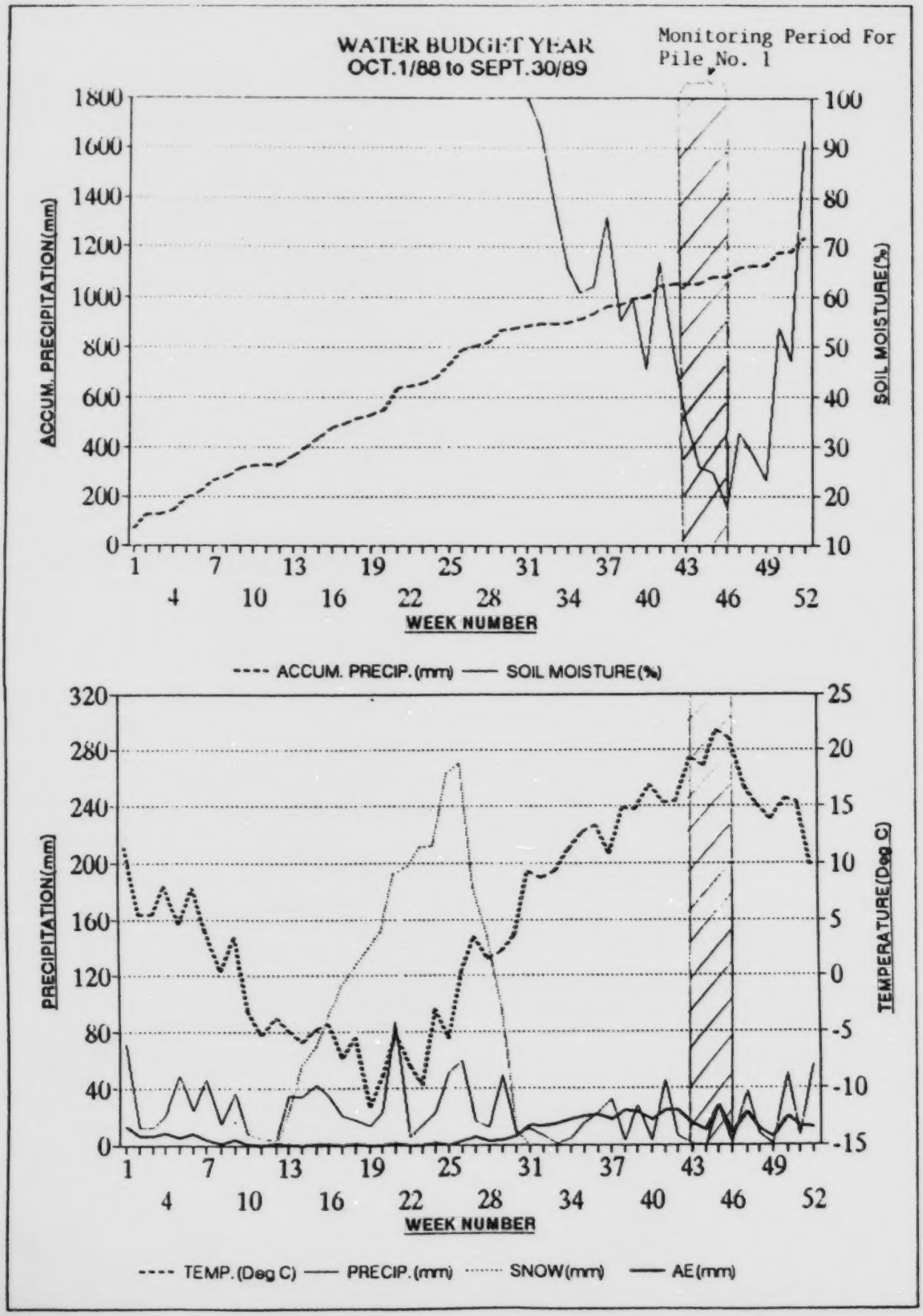
After the dry summer however both years (although primarily 1990) exhibited elevated rainfall during the fall months. Specifically in 1989, September, October and November were higher than the Normal and 10 year mean;with November exceeding the 10 year mean by greater than 1 SD. However, December recorded excessively low precipitation which was greater than 1 SD from the 10 year mean, and greater than 2 SD from the 30 year Normal. During the fall of 1990 September, October, and December exhibited precipitation exceeding 1 SD above the 30 year Normal. December also exceeded the 10 year mean by greater than 1 SD.

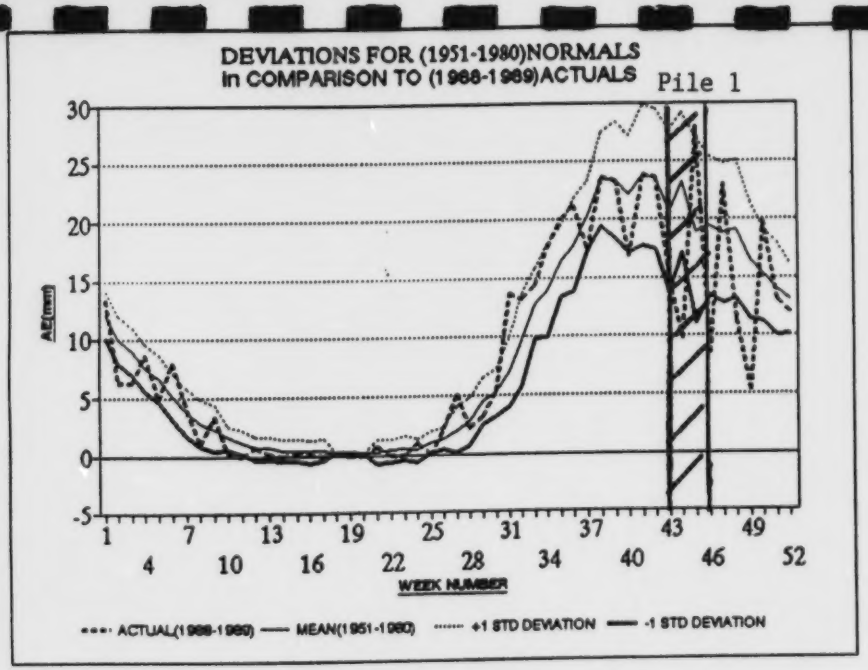
2.3 Water Balance Analysis

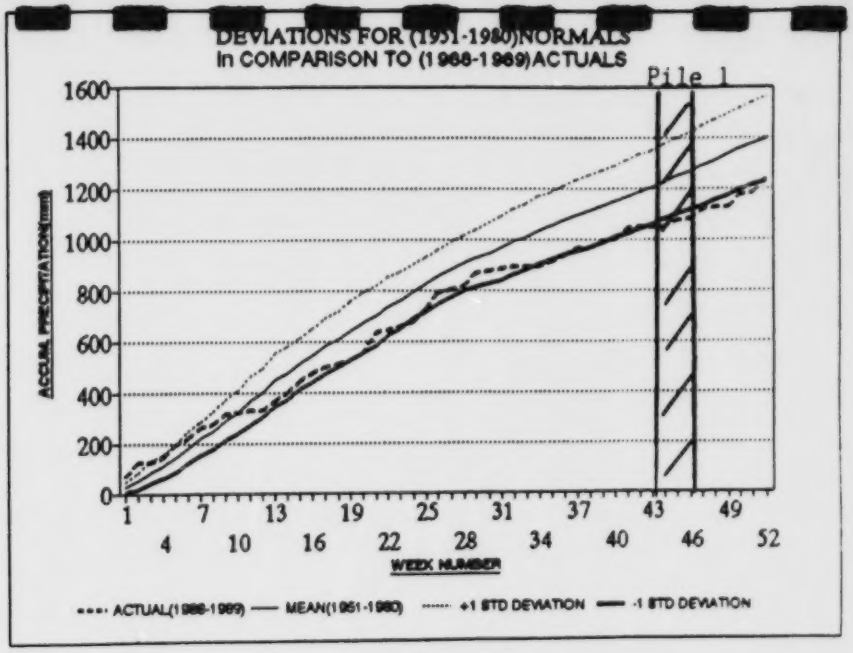
Given the variability in summer and fall rainfall, it was decided to assess the hydrologic budget equation for the two water years within which the study was carried out, namely October 1, 1988 to September 30, 1989 and October 1, 1989 to September 30, 1990. As the monitoring for the last pile carried over into beginning of the following water year. data is presented up to December 1990.

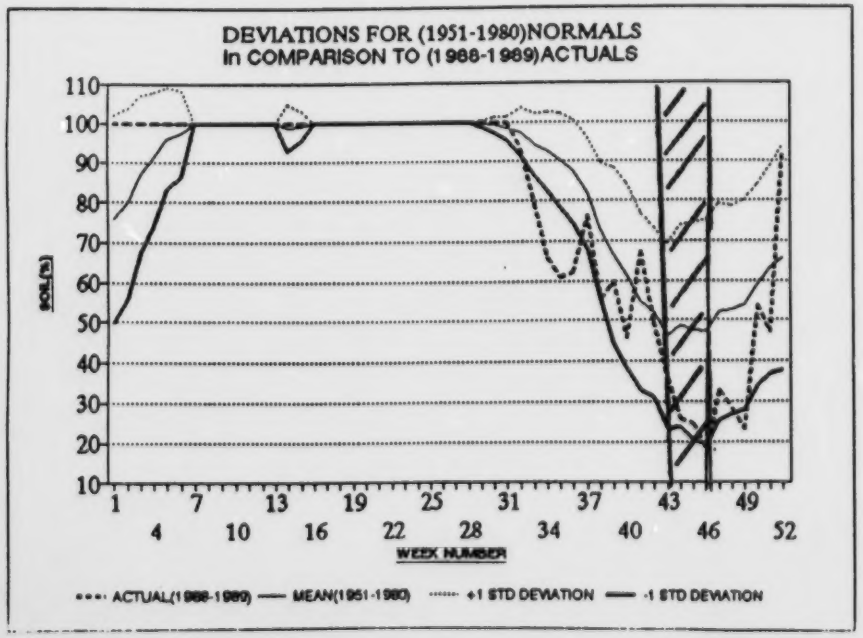
The actual data for the 1988-89 and 1989-90 budget years are presented graphically in Figures 2-3 and 2-5 respectively. The data for each water year is then compared to the 30 year Normal values (with its 1 SD envelope) on Figures 2-4 and 2-6 respectively. The data is plotted against time, in terms of weeks, with week 1 commencing October 1.

FIGURE 2-3


WATER BUDGET YEAR
OCT.1/88 to SEPT.30/89
Monitoring Period For
Pile No. 1
ACCUM. PRECIPITATION(mm)
SOIL MOISTURE(%)
WEEK NUMBER
---- ACCUM. PRECIP.(mm) —— SOIL MOISTURE(%)
PRECIPITATION(mm)
TEMPERATURE(Deg C)
WEEK NUMBER
---- TEMP.(Deg C) —— PRECIP.(mm) ····· SNOW(mm) —— AE(mm)


DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1988-1989)ACTUALS
Pile 1
AE(mm)
WEEK NUMBER
ACTUAL(1988-1989)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION


DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1988-1989)ACTUALS
Pile 1
ACCUM. PRECIPITATION(mm)
WEEK NUMBER
ACTUAL(1988-1989)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION


DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1988-1989)ACTUALS
SOIL(%)
WEEK NUMBER
ACTUAL(1988-1989)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION

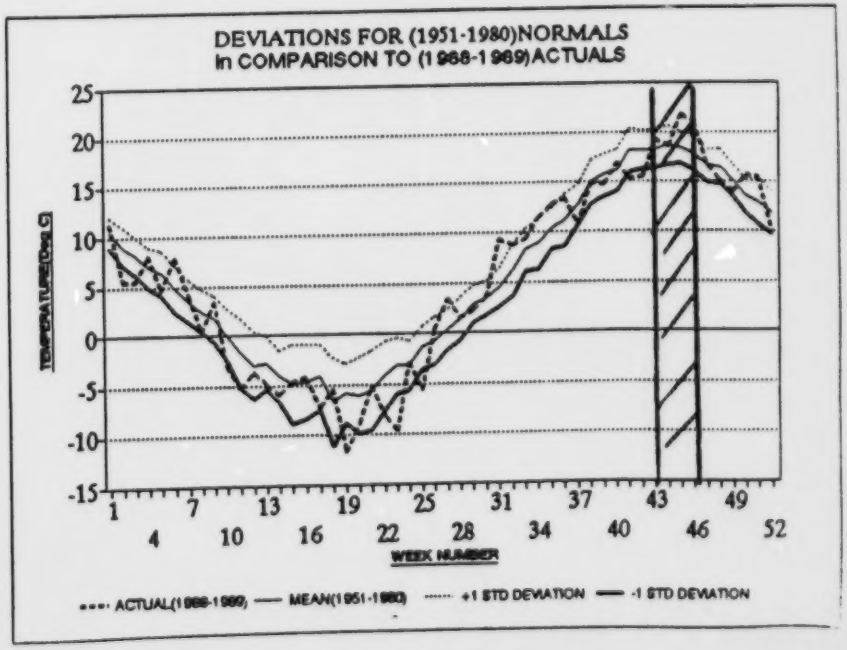
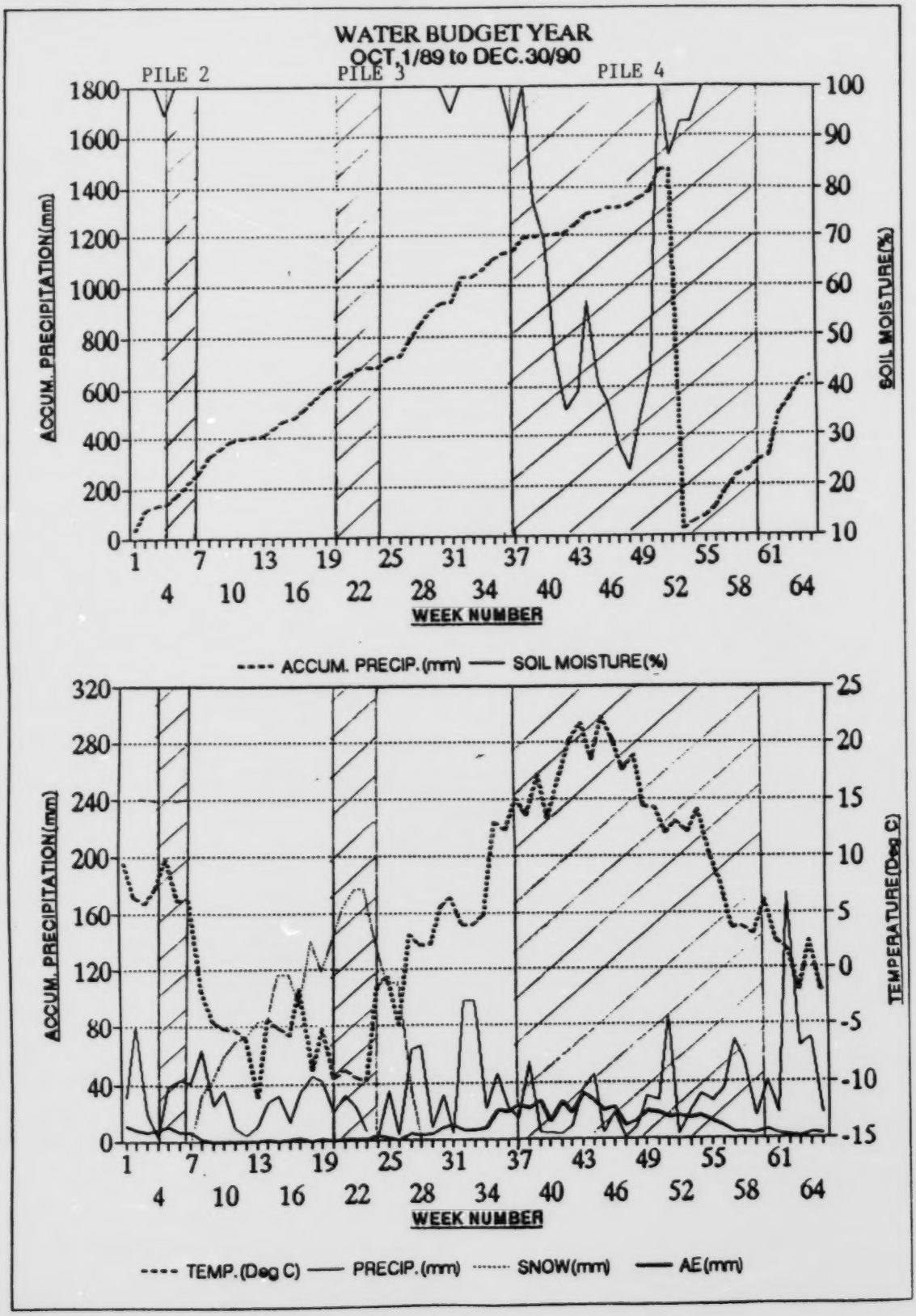
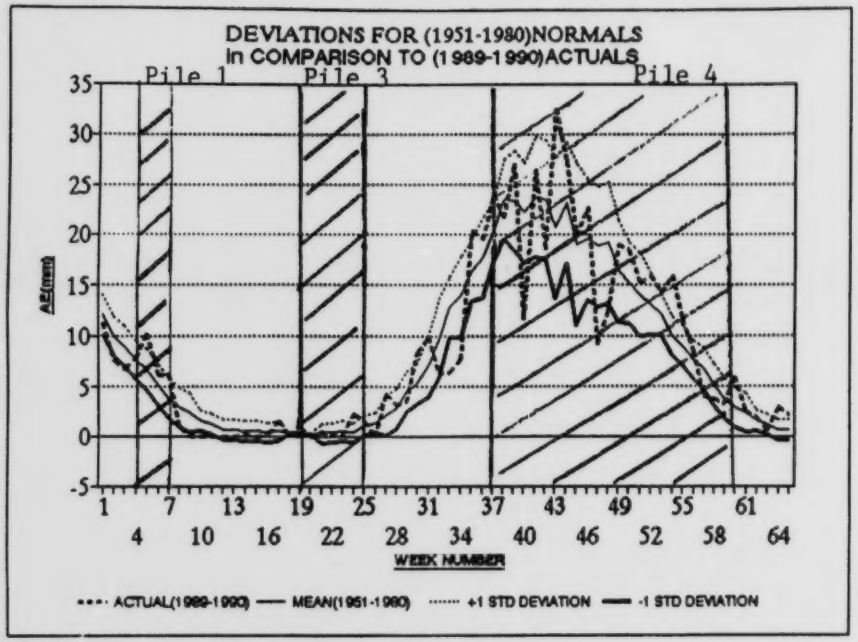
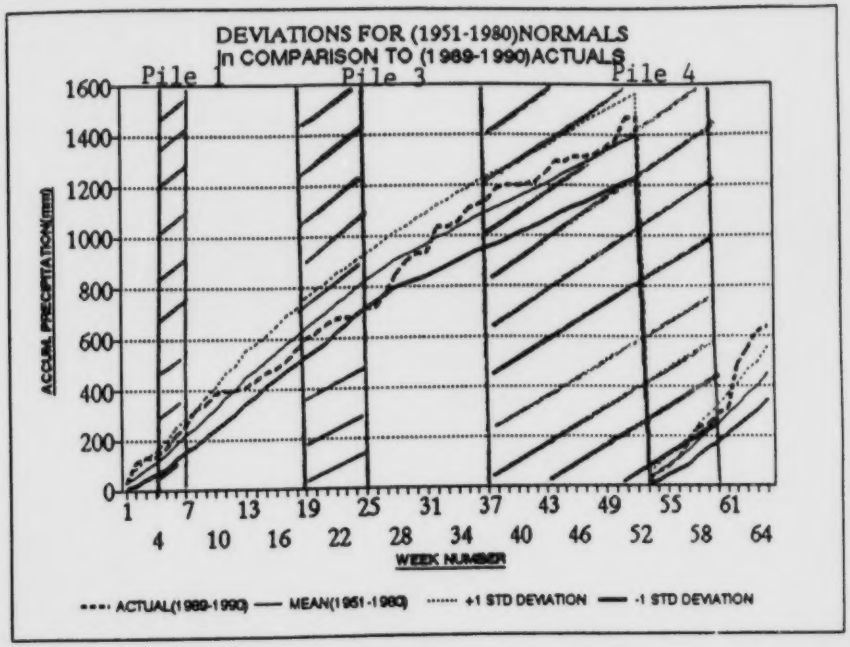

DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1988-1989)ACTUALS
TEMPERATURE(Deg C)
WEEK NUMBER
ACTUAL(1988-1989)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION

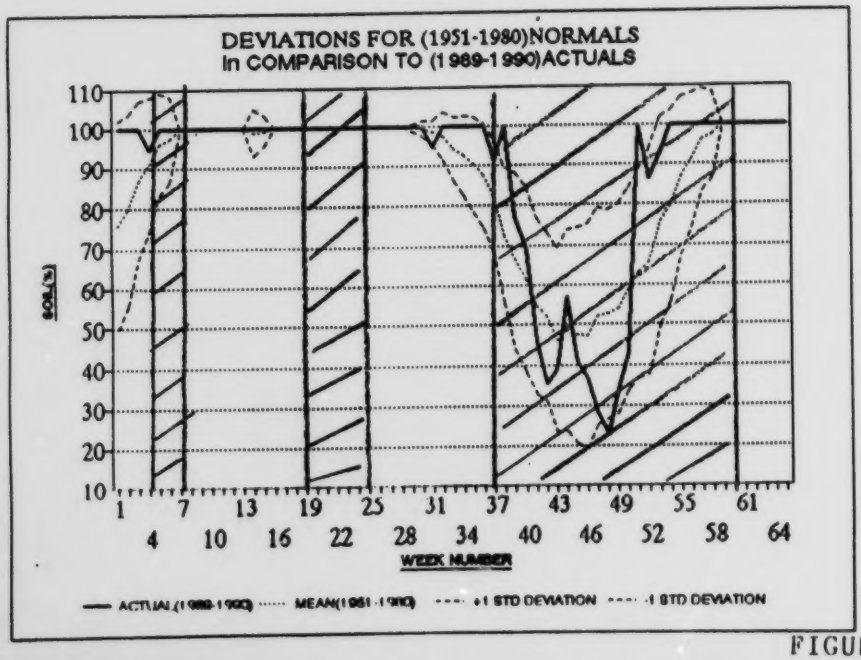
FIGURE 2-4

FIGURE 2-5


WATER BUDGET YEAR
OCT.1/89 to DEC.30/90
PILE 2
PILE 3
PILE 4
ACCUM. PRECIPITATION(mm)
SOIL MOISTURE(%)
WEEK NUMBER
---- ACCUM. PRECIP.(mm) —— SOIL MOISTURE(%)
ACCUM. PRECIPITATION(mm)
TEMPERATURE(Deg C)
WEEK NUMBER
---- TEMP.(Deg C) —— PRECIP.(mm) ····· SNOW(mm) —— AE(mm)


DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1989-1990)ACTUALS
Pile 1
Pile 3
Pile 4
WEEK NUMBER
ACTUAL(1989-1990)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION


DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1989-1990)ACTUALS
Pile 1
Pile 3
Pile 4
WEEK NUMBER
ACTUAL(1989-1990)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION


DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1989-1990)ACTUALS
WEEK NUMBER
ACTUAL(1989-1990)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION

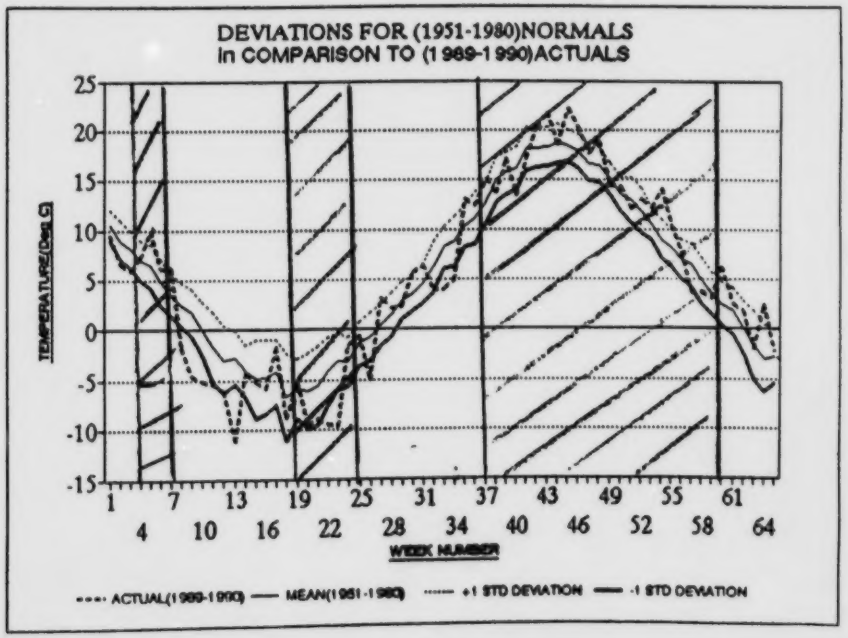

DEVIATIONS FOR (1951-1980)NORMALS
In COMPARISON TO (1989-1990)ACTUALS
WEEK NUMBER
ACTUAL(1989-1990)
MEAN(1951-1980)
+1 STD DEVIATION
-1 STD DEVIATION

FIGURE 2-6

2.3.1 1988 - 1989 Water Year

The pertinent points which can be derived from the water budget analysis are summarized below:

1) There was a significant reduction in soil moisture, down to the 20 - 30%, level during the summer months, particularly in August and early September. During that period, levels were at or exceeding 1 SD below the Normal value of around 50%.

2) This decline appears to be attributable to slightly elevated air temperatures and variability in evapotranspiration, but mainly to reduced precipitation. The accumulated precipitation declines below 1 SD from the 30 year Normal during this period.

2.3.2 1989 - 1990 Water Year

Pertinent points from the budget analysis include:

1) There was a significant reduction in soil moisture down to 20 - 40% during the summer, in comparison with the 48 - 50% Normal value. This period remained below the 50% value for a longer duration (10 weeks, between week 40 - 50) than the Normal period (week 42 - 47). There is also one peak which declines below 1 SD.

2) This decline in soil moisture appears to be attributed to higher air temperatures, high fluctuations in evapotranspiration and reduced precipitation. Air temperatures exceeded 20^{0}C, whereas the Normal doesn't exceed 18^{0}C.

3) The accumulated precipitation notes low precipitation between week 13 and 31 (December 24 - May 6) with less than 1 SD at one time in the April period. This results in less water available during the spring groundwater recharge period.

4) Due to the fall rains, soil moistures were brought back up to 100% in both 1989 and 1990. Therefore, dry conditions were not carried over into the next water year

2.3.3 Surface Water Discharge/Groundwater Storage Components

To assess whether the trends in climate parameters within the water budget analysis were significant enough to cause changes within the surface and groundwater components of the hydrologic cycle, a brief assessment was made of variability in surface water discharge and groundwater storage components.

Surface water discharge variability was assessed by utilizing automated gauging records from MacAskill Brook, a 17.2 km^2 natural watershed with unregulated flow, located some 10 km southeast of the site. The 1980-89 decadal mean was 21,720 cubic decameter (dam^3, with a 1 SD of 3,865 dam^3). The 1989 calendar year was lower than 1 SD and almost 2 SD from this mean. This was attributable to lower than mean monthly flows, principally in June, July, August and September, with August being greater than 1 SD below the mean. The data for 1990 was not available at the time of reporting.

Variation in groundwater storage was determined from seven years of automated water level readings at the Nova Scotia Dept. of Environment's "Sydney" recorder. This monitoring well assesses head changes in an artesian bedrock aquifer, located some 11 km southwest of the site. Although this data is not representative of the water table aquifer conditions found within the pile, the relative changes were expected to provide an idea of the degree of change between years. The data Figure 2-7 portrays the mean monthly water level (average of the high and low for each month) compared to the 1 SD envelope around the 1980 -89 decadal mean.

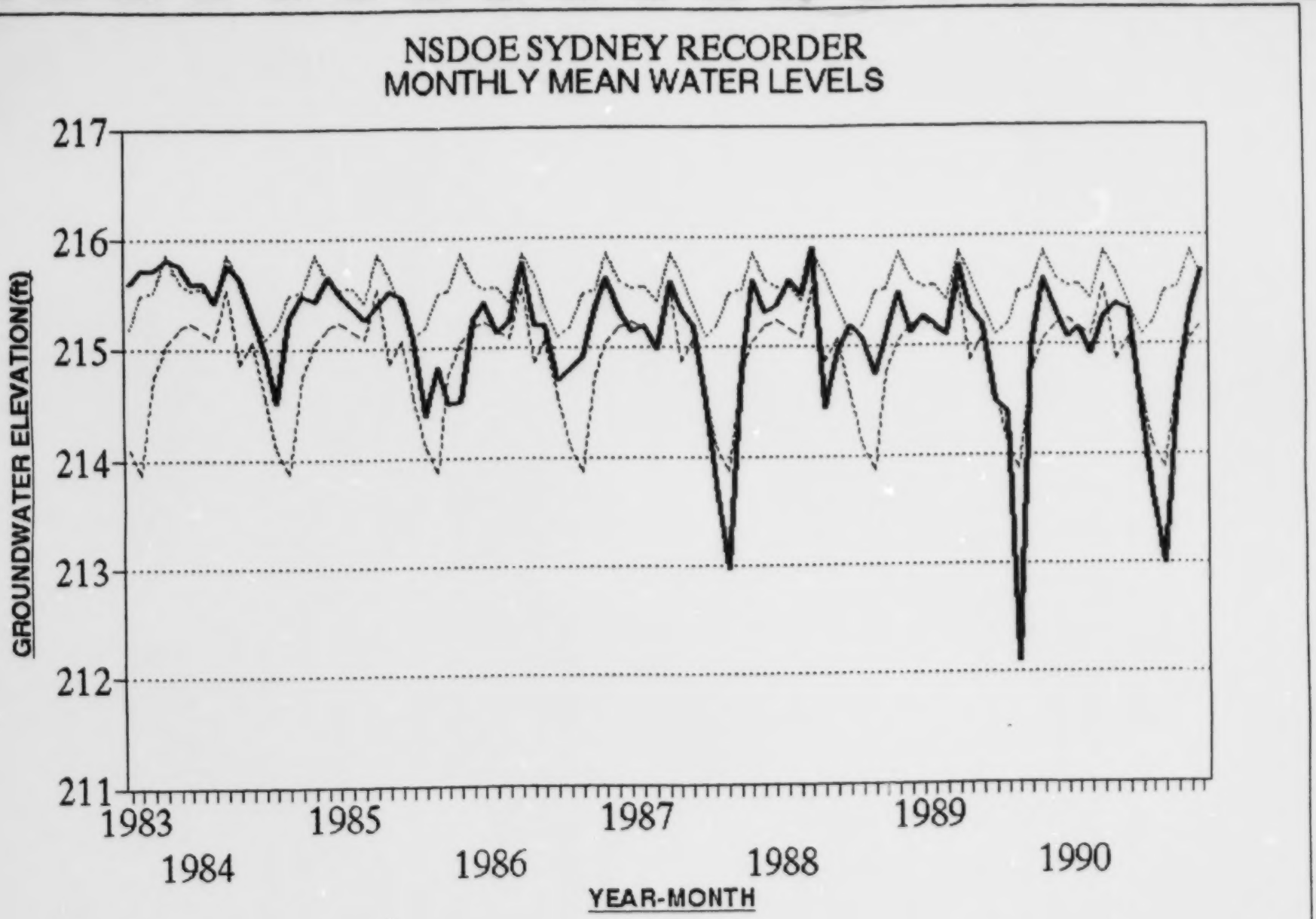

NSDOE SYDNEY RECORDER
MONTHLY MEAN WATER LEVELS
GROUNDWATER ELEVATION(ft)
217
216
215
214
213
212
211
1983
1984
1985
1986
1987
1988
1989
1990
YEAR-MONTH
MONTHLY MEANS(ft)
+1 STD(ft)
-1 STD(ft)

FIGURE 2-7

Both 1989 and 1990 exhibited significant summer declines in water levels to the extent of being greater than 1 SD from the mean. This correlates with the reduced rainfall during the summer months in those years, the lower soil moistures and low streamflow previously discussed.

2.4 Summary

In summation, 1989 and 1990 exhibited dry, hot summers around the Sydney area. This resulted in significant reduced stream flows and groundwater levels. However, on an annual basis there is a continued long term trend of increasing total annual precipitation, due principally to increased fall rains. The recharge occurring during this period brought groundwater and soil moisture storage levels back up to their normal position, so that the "low" conditions were not carried over from year to year.

3.0 OPERATIONAL PROCEDURES

The key operational procedures employed at the LBC for constructing, storing and removal (lifting) of the coal piles, which are pertinent to this study are discussed below. With the exception of dimensions and timing, all procedures were employed at each monitored pile, and represent normal operating conditions.

1) All four piles were constructed in generally the same manner. Coal is brought onto the LBC by rubber tyred coal haulers (Plate 3). These transports also are responsible for dumping the coal through bottom end dumpers on initially the asphalt floor, and latter over the top of the pile. The specific equipment employed includes CAT 768 (80 tonne) and Euclid 870 (70 tonne) tractors hauling Atlas (70 short ton) trailers. At times CAT 631 scrapers with 24 m^3 capacity may also be used.

Once deposited in "windrows" (1 - 2 m in width and height) a rubber tyred CAT 824 dozer with a 18 m^3 push blade is utilized to spread and shape the top of the pile (Plate 4). These dozers utilize tires loaded with a calcium/chloride/water mixture to improve compaction and traction.

This method creates a characteristic rectangular planimetric shape, a convex upward longitudinal profile, and a triangular shaped transverse profile with the top cut off flat (note Plates 2 & 5)). Given the configuration of the LBC, the long axis of all the pile is oriented northwest - southeast.

The dimensions of the piles varied depending upon contracts, timing of shipments, and mine production. The dimensions recorded ranged from 230 - 330 m long, by 55-60 m wide, by 10-12 m high [Piles No 1 and 4, Plate # 2]. The minimum top width of the pile is considered to be approximately 6 m for vehicle safety considerations. The range in tonnages stored in the piles monitored ranged from 30,000 to 131,000 tonnes.

There is a large variation in the time required to build a pile up to its maximum extent. The longest time monitored was Pile No 1, which required 50 days. Similarly once the degassing period is over, there is a large variation in the length of time taken to remove the pile; being a function of market conditions, labour considerations, but more so ship arrivals. Pile No. 4 had the longest removal period of some 141 days.

2) The dumping procedure utilized, was to access the pile from the same end throughout the construction period. Therefore one end of the pile was always more compacted due to the weight of the fully loaded transports; while the off-ramp end was not as heavily compacted. Utilizing a loaded weight for the coal hauler of 107.9 tonnes, a contact area for the tires of 0.3 - 0.46 m^2, and assuming an equally distributed weight, gave a pressure of 50 - 75 tonnes/m^2 (500 - 750 kPA). If unloaded (44.4 tonnes) this decreases to 20 - 30 tonnes/m^2 (200 - 300 kPA). The rubber tyred dozers created a pressure of 19 - 28 tonnes/m^2 (190 - 280 kPA).

These operations resulted in a very compact core of coal under the travelled area of the pile. Most of the compaction results from the heavier, and more continuous movement of the coal haulers. The method of creating the piles results in a subdued, convex, longitudinal profile (Plate 2).

3) Vehicle operations over the top of the pile resulted in an essentially flat, transverse profile (Plate 5) to within 5 m of the toe of either side of the pile. The side slopes were therefore steep, being created by the loose dumping of coal over the side by the loaders, thereby allowing the coal to achieve its natural angle of repose (35^0) (Plates 2 & 4). This resulted in a transverse profile configuration characterized by a compacted top and loose sides. During this study period rollers were not utilized to compact the side slopes (Plate 2).

4) Removal of the pile for loading onto the railcars employed the use of CAT dozers to excavate along the base of the side of the pile and undermine it (Plate 6). Due to the compactness of the material, full collapse did not always occur, even with vertical slopes. Similar equipment was therefore in use on the top of the pile to push material over the edge (Plate 7). In some instances, the top of the pile was so compacted that it was necessary to rip it with a dozer before it could be successfully removed.

5) If space was at a premium, two piles were constructed such as to build off the end of the initial pile.

6) With the construction of one independent pile, the method of construction was to establish a relatively long, wide base prior to building upward. As the pile grew, most of the expansion was upward, with secondary expansion in a longitudinal direction, and minor lateral development. Therefore surface area exposed to rainfall expands rapidly initially, and then much slower as the height is increased.

7) This method of construction does create a relatively more compact structure, rather than a loose open configuration if constructed from a stacker-reclaimer system. However, for the Met piles this is preferred, to ensure the minimum of oxygen diffusion into the piles, which would act to alter the fluidity of the coal. The compactness ensures that the coal is bathed in methane as it degasses. This also aids in reducing the formation of acid drainage.

8) Spontaneous combustion within Met piles is unknown. None of the monitored piles exhibited any such occurrence.

9) Dry summer conditions necessitate dust control measures, which is usually provided by rubber tyred water tankers. On Pile 4, a dust suppressant was utilized on an experimental basis.

10) If problems were present in controlling the sulphur content during pile construction, then fines may be reduced within the incoming coal. Therefore, some piles exhibit a coarser, and therefore, possibly a more permeable texture.

11) As the pile weathers over the degassing and removal period, erosional gullies form along both the sides and ends. This requires, in the worst case, removal of the fan shaped deltas of material along the sides by the CAT dozers, in order to keep the perimeter drains free and to maintain access for on-site vehicles.

4.0 FIELD DATA

The data collected in the field, upon which the discussion, conclusion, and recommendations are based, are presented in a separate Appendix for each respective pile (Appendices 2 - 5).

Table 4-1 summarizes the pertinent data regarding volumes, size, and character of the coal piles, as well as the type of instrumentation installed, and testing undertaken.

As can be noted, Pile 1 was the most intensively studied, followed by Pile 4. This was a result not only of the timing, but more importantly the problems associated with attempting to monitor operational piles during specific times of the year without seriously hampering day-to-day operations.

5.0 CONCEPTUAL/ANALYTICAL MODEL FOR THE HYDROLOGIC CYCLE OF LARGE COAL PILES

5.1 Overview

Based upon the data and observations recorded to date, the pertinent components of the coal pile hydrologic cycle are presented in equation and canonical form in Figure 5-1. Figure 5 - 2 presents the components in a conceptual view. A description of the pertinent aspects of this model are discussed below in terms of the "Systems Approach", as defined by Chlorley and Kennedy (1971). This is augmented by Toth's (1970) conceptual groundwater flow model, which relies on the integration of the "Hydrogeologic Environment" and the "Groundwater Regime". What is known about the pertinent hydrogeological characteristics of the coal (Regime parameters) is discussed below in Section 5.2. The climatic conditions within the Hydrogeological Environment were discussed in Section 2.0. Its relevance to groundwater recharge is summarized in Section 5.3.

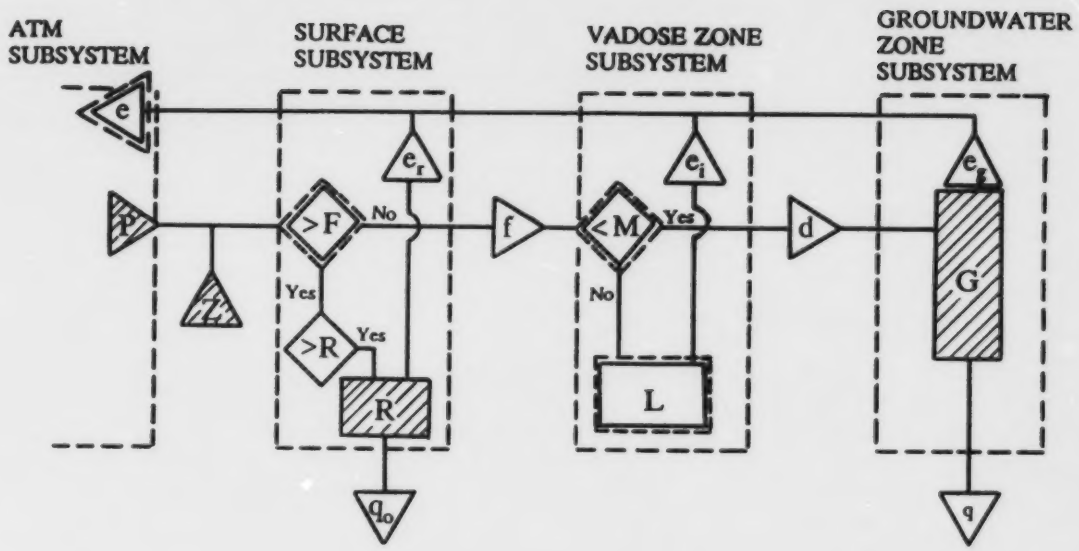
TABLE 4-1
SUMMARY of PERTINANT DATA
COLLECTED ON EACH PILE MONITORED

PILE	PERIOD MONITORED	TONNAGE IN STORAGE (tonnes)	CHARACTER %ASH (DRY)	CHARACTER %S (DRY)	TOT. PREC. REC'D DURING MONITORING PER. (3)	DIMENSIONS OF PILE	INSTRUMENTATION NO. OF PEIZ. (4)	INSTRUMENTATION NO. OF THERMO. (5)	INSTRUMENTATION NO. OF MEAS. (6)	MOISTURE CONTENTS INCOM. COAL (7)	MOISTURE CONTENTS SPLIT SPNS (8)	MOISTURE CONTENTS REMOV. COAL (9)	HYDRAULIC CONDUCTIVIT. SLUG/TEST.	(10) GRAIN SIZE ANAL IN/OUT COAL	(10) GRAIN SIZE ANAL SPLIT SPNS	FIELD INSPECT.
Pile No. 1 No. 65 Thermal Bank	20 days July 27 - Aug.16/89 (Inclusive)	87,356.5	(1) 5.76	(1) 2.22	29.0mm	Length 305m Width 30m Max Height 9m	7 at 7 Sites	N/A	19	82	42	6	4	4	11	14
Pile No. 2 No. 74 Met Bank	18 days Oct.31 - Nov.17/89 (Inclusive)	(*)	(2) 3.6	(2) 1.26	117.4mm	Length * Width 45m Max Height 8m	6 at 6 Sites	N/A	25	0	33	2	0	2	0	1
Pile No. 3 No. 77 Met Bank	25 days Mar.6 - Apr.01/90 (Inclusive)	31,000+	(2) 3.01	(2) 1.25	40.6mm	Length 150m Width 45m Max Height 10m	5 at 6 Sites	Tot. of 10 5 at each of 2 Sites	26	0	30	2	0	1	0	3
Pile No. 4 No. 74 Met Bank	131 days July 12 - Nov.20/90	131,000	(1) 2.98	(1) 1.24	529.5mm	Length 275m Width 45m Max Height 15m	5 at 5 Sites	Tot. of 5 at One Site	34	0	42	2	0	2	0	5

1) Weighted Average of Incoming Coal.
2) Samples Collected During Vessel Loading.
*) Length and Tonnage Data Not Possible as Monitored Area Only Formed Part of a Much Larger Pile.

3) Total Precipitation
4) Piezometers
5) Thermocouples
6) Measurements
7) Incoming
8) Split Spoon
9) Removing
10) Grain Size Analysis

CANONICAL REPRESENTATION



SYMBOLS

- INPUT
- OUTPUT
- REGULATOR
- STORAGE
- DIRECT
- IN-DIRECT (qualitative)

} PARAMETERS BEING MONITORED

WATER BUDGET EQUATION

$$P+Z = q_o + q + e_r + e_i + e_g \pm \Delta R \pm \Delta L \pm \Delta G$$

PARAMETER DEFINITIONS

INPUTS

P - PRECIPITATION
Z - MOISTURE BROUGHT IN WITH COAL
f - INFILTRATION BELOW SURFACE
d - DEEP PERCULATION

REGULATORS

F - INFILTRATION CAPACITY
M - FIELD MOISTURE CAPACITY
R - SURFACE DETENTION

OUTPUTS

q_o - SURFACE WATER DISCHARGE
q - GROUNDWATER DISCHARGE
e_r - EVAPORATION FROM SURFACE
e_i - EVAPORATION FROM AERATION ZONE
e_g - EVAPORATION FROM GROUNDWATER DIRECTLY AT TOE OF SLOPES

STORAGE

R - SURFACE
L - VADOSE ZONE
G - GROUNDWATER

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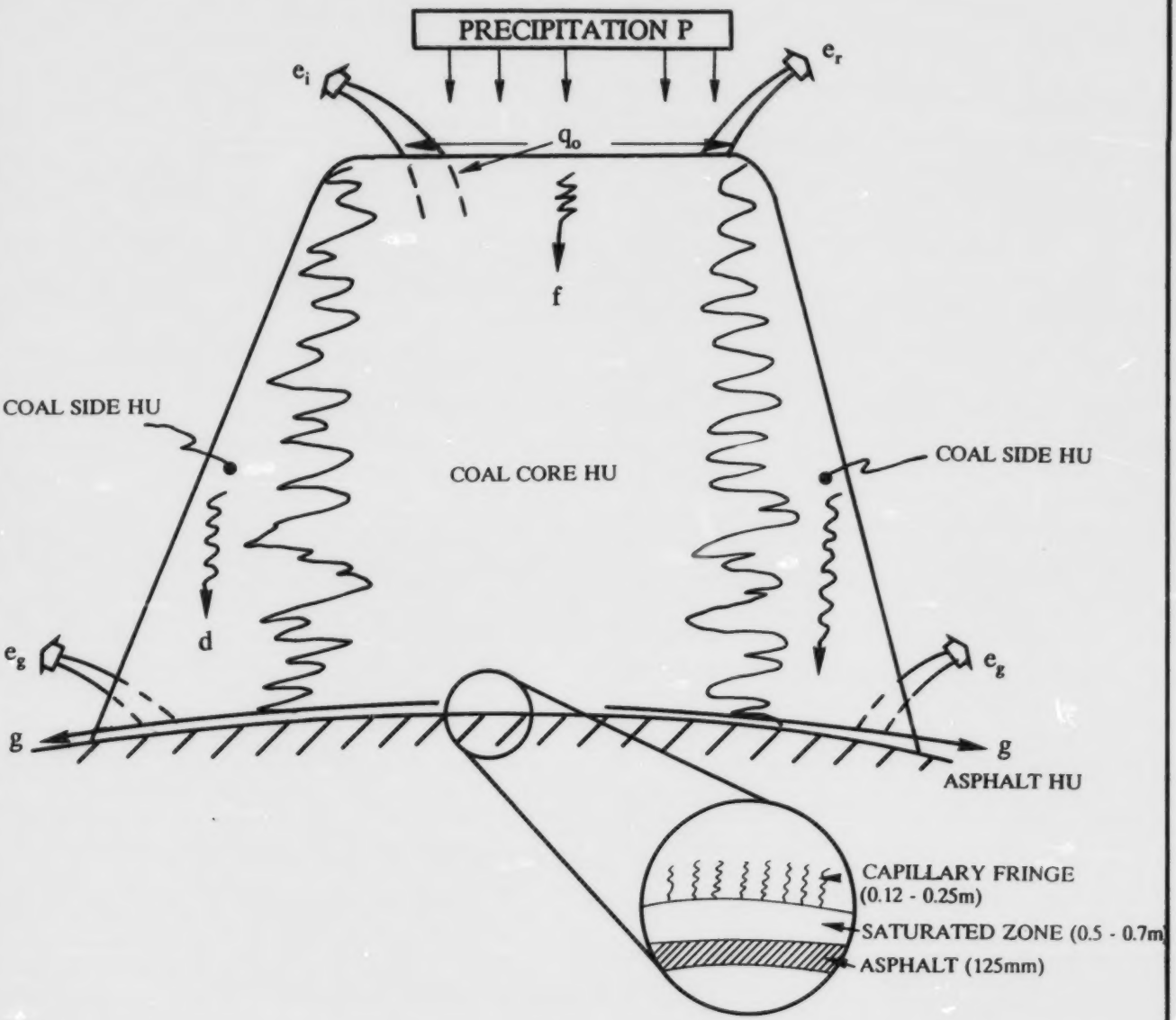
FIGURE 5-1
HYDROLOGIC CYCLE
FOR COAL STOCKPILE



FOR NOMENCLATURE NOTE FIGURE 5-1

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FIGURE 5-2
CONCEPTUAL VIEW OF HYDROLOGIC CYCLE

It is assumed that the fluid in the following discussion is water, which does not attain significant alterations in density or viscosity as it moves through the pile. This is supported by the water chemical analyses taken from ground and surface waters.

Throughout the discussion the reader should refer to Figure 5-1 and the plates given in Appendix 1.

5.2 Hydrostratigraphic Units

There are three key hydrostratigraphic units (HU) which govern the ground/surface water flow systems developed on/within the coal piles, namely: 1) Coal Core HU, 2) Coal Side HU, and 3) Asphalt HU. Given the level-of-effort for the program, these HU's are defined at a macro scale, and assume the validity of the Darcy Continuum approach.

5.2.1 Coal Core HU

The Coal Core HU comprises the centre compacted core of the coal bank. It can best be characterized on a macro scale as a homogeneous, isotropic, porous, semi-consolidated, non-fractured, compressible, media (Plates 6 and 8), which forms what will be referred to as a water table aquifer.

The macro scale homogeneity is apparent from the grain size analyses of incoming raw coal (note Drawing 01), resulting in relatively uniform, high, intrinsic permeabilities ranging from 3.6×10^{-1} to 6.3×10^{-2} cm/sec (Hazen method). However grain size analyses carried out on the coal after it was compacted in the pile, provide intrinsic permeablities of 2.3 to 3.2×10^{-2} cm/sec. Hydraulic Conductivities (K) derived from four slug tests on PNs 1,2,3 and 4 within Pile 1 indicated values of 1.6×10^{-6}, 1.8 X

10^{-6}, 5.7 X 10^{-6} cm/sec. respectively. The latter values are expected to be more representative. The compressibility of the media and the compaction by vehicular traffic has therefore combined to produce a low K media, with an apparent macro scale homogeneity.

However during deposition and compaction within the pile, a layered heterogeneity is noticeable in certain areas, both from visual inspections during removal (Plate 8), as well as the fluctuations in N or relative density values obtained during drilling. In terms of the latter the following points are of note:

Pile 1:

PN 1 and 4, positioned in the centre line of the pile, exhibit very high relatively density from the top down, due to loading by traffic. PN 4 exhibits greater values to depth, probably a function of being on the "on-ramp" end of the pile. At PN 5 however, which is also located on the centre line, all values are relatively low since it is positioned over the "off-ramp" end of the pile. Along the edge of the pile at PN 2 and 3 relatively low values were found at top, since trucks did not go that close to the edge of the pile. Both increase slightly with depth, probably due to the surcharging factor. All holes indicate some variations in N value with depth supporting the heterogeneity concept.

Piles 3 and 4:

Pile 3 shows slightly higher surface N values on the "on" versus the "off" ramp. As well as at the "centre" versus "edge" of the piles. Two, show a constant increasing trend with depth; the remainder fluctuate. Pile 4 indicated relatively similar surface densities at both the "on" and "off" ramps. The most compacted area was over the pile from one side to the other. All holes indicated fluctuations. There is, therefore, no consistent trend noted in all piles, either in areal or vertical extent.

Porosity is expected to theoretically range from 19 - 28%; assuming unit weights ranging from 1070 to 1162 kg/m^3 (Nolan Davis 1986). The effective porosity and field capacity are unknown.

5.2.2 Coal Side HU

The Coal Side HU comprises the loose side walls of the coal bank, being positioned on either side of the Coal Core HU (Plates 2 and 4). It can best be characterized on a macro scale as a homogeneous, isotropic, porous, loose, non-fractured, compressible media, which is also considered to form part of the water table aquifer.

Slug testing could not be carried out due to the absence of a saturated zone within the piezometers in this HU. The intrinsic permeabilities derived from the grain size analyses of loose incoming coal of 10^{-2} cm/sec. are thought to best represent this HU. Porosity is expected to exceed 30%; effective porosity and field capacity are unknown.

5.2.3 Asphalt HU

The Asphalt HU comprises the asphalt base upon which the coal piles are placed. It can best be characterized on a macro scale as a homogeneous, isotropic, porous, consolidated, non-fractured, non-compressive media. It is assumed to form an aquitard beneath the pile. Literature values suggest a hydraulic conductivity of less than 1×10^{-7} cm/sec.; with a porosity of 4-5%.

The surface of this unit is crowned so as to divert any surface drainage over it to the east and west as noted on Figure 5-2. The crown is positioned along the centre line of the pad for each pile.

5.3 Atmospheric Subsystem

A discussion of the water balance related to precipitation input and loss to the atmosphere of water through evapotranspiration was presented in Section 2.0.

However, in terms of coal piles the only "loss" component results from evaporation; transpiration is not present. This component not only includes heating from the surrounding air mass, but also the albedo of the reflecting surface, which is black coal. Therefore the relatively large absorption of solar radiation, (low albedo) of the surface in question, is expected to increase evaporation losses over what is theoretically calculated, utilizing the Thornthwaite Index.

Given the latitude of the study area, the variability in temperature is sufficient enough to develop a snow cover and frost during the winter months. However, the radiation heating by the coal alters this development over the pile to an unknown degree.

The heat generated within the interior of the pile itself is discussed under the Vadose Zone Subsystem. The amount/type of evaporative losses within each subsystem are discussed in the respective sections.

The role of climatic factors on influencing groundwater recharge is controlled by the balance achieved between precipitation input and evaporative loses. This relationship is presented in Figure 5 - 3, based upon 30 year Normal conditions.

The Sydney area receives a relatively large volume of precipitation with relatively low evapotranspiration. This results in a low annual moisture deficit of 0.58 cm and a large annual surplus of 29.4 cm. The annual surplus arrives over (nine) 9 months in

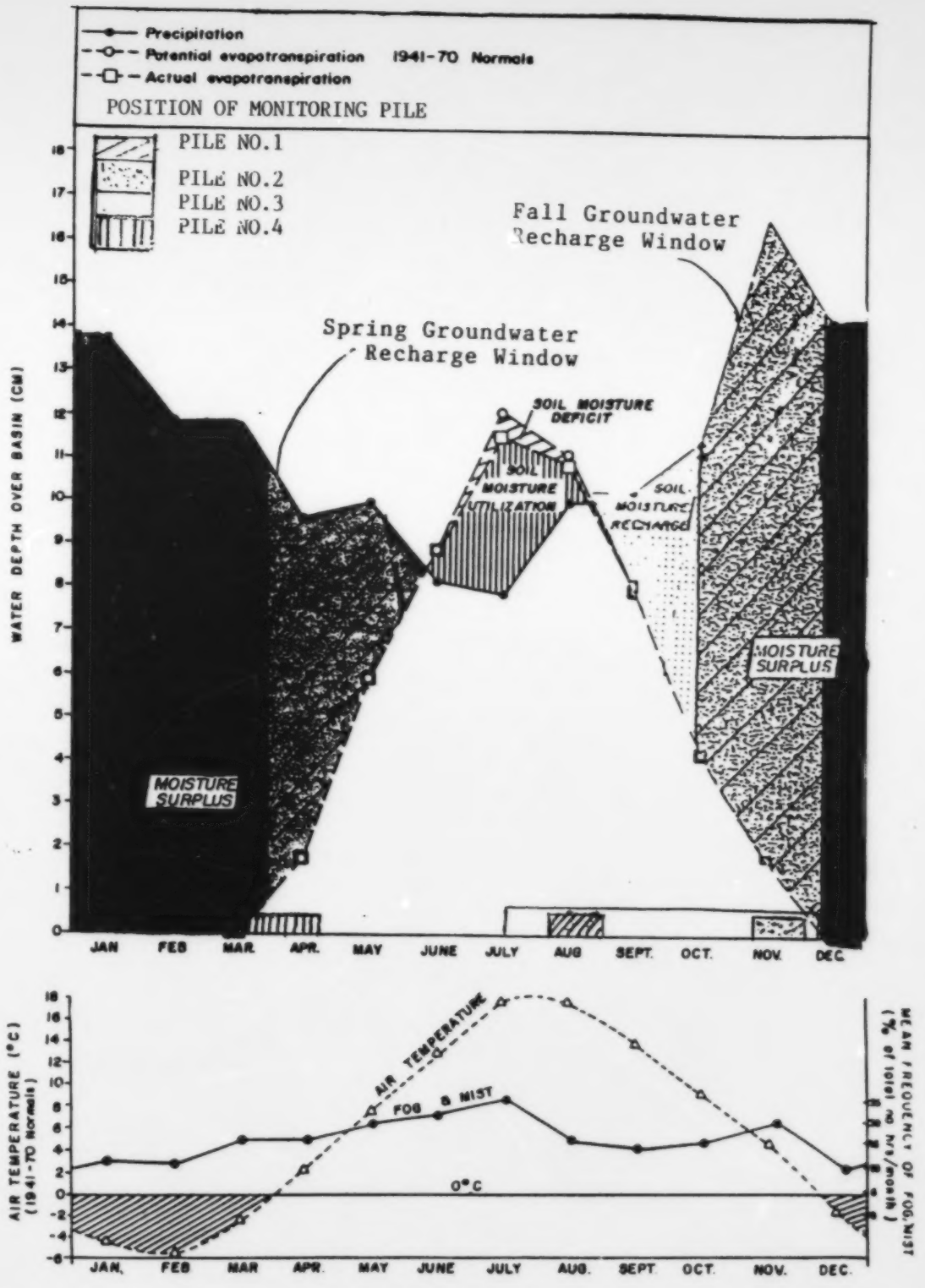

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FIGURE 5-3
WATER BALANCE DIAGRAM
SYDNEY AREA

two distinct wet seasons: a) winter - early spring (January - May inclusive) and b) late fall (October - December inclusive). Warming trends in March, and more specifically in April/May, release the snowpack storage and eliminate frost cover allowing for a major groundwater recharge "window" in March - May inclusive.

The second wet season (October - December) creates the second major "recharge" window. During the summer months (May - September) evapotranspiration rates exceed precipitation, peaking in July. The result is the recession curve seen in both streamflow and groundwater hydrographs. The deficits in soil moisture incurred in June, July and August are quickly replenished in September. During this replenishment, the recession curves bottom out.

Pile 1 is positioned within the soil moisture deficit region of the annual cycle. Piles 2 and 3 were positioned within the fall and spring recharge windows respectively. Pile 4 spanned both the moisture deficit and fall recharge window.

5.4 Surface Subsystem

Surface runoff (q_o) was not instrumented at this stage of the investigation. Therefore movement of water in response to rainfall events was determined through visual site inspections. This allowed for a qualitative understanding of the runoff process.

Three main classes of surfaces were noticeable over the piles, namely: 1) "compact" - packed down by vehicular traffic and would not leave a footprint (Plate 9), 2) " partially compacted" by backblading with the bucket on the loaders and characterized by allowing footprints of less than 2 - 3 cm in depth (plate 10), and 3) "loose" - dumped loosely in place, which allowed a relatively deep footprint to be left (plate 11). After construction, most of the travelled area on top of the pile was characterized by a Class 1

surface. The two exceptions were along the edges and over the off-ramp. During construction Class 1 and 2 surfaces were present over the top. A Class 3 surface was always present over the sidewalls.

From a visual assessment, these surfaces allowed the Surface Subsystem to respond to rainfall events by generating a relatively large amount of surface runoff (q_o) which was transported by Horton overland flow across the top of the compacted core of the pile (plate 12). There was minimal depression surface storage (R). The critical regulator governing this flow is F (Infiltration Capacity).

However the low rainfall intensities, characteristic of the local climate, were not always sufficient enough to create widespread sheet flow over the surface. The dampness noted over the surface, may have either infiltrated into the top few cm of the Class 2 surface and/or evaporated. If a Class 2 surface was present, some interflow may have been generated, but only on a localized basis.

Surface wet areas were also in evidence at selected times while the pile was under construction, due to the compression of incoming coal by vehicular traffic, if it had a relatively high moisture content. Operational personnel indicated that if the moisture contents exceeded approximately 10%, trafficability was significantly impaired; since with agitation the water rose to the surface of the pile.

That component of the surface runoff which is directed laterally toward the side of the pile, (Coal Side HU) could undergo three different processes, namely:

1) It could readily infiltrate down into the Vadose Zone Subsystem through infiltration (f).

2) In certain situations, where the flow over the top became concentrated into a channel before it reached the edge, the result was the formation of an erosional gully. At times these reached the asphalt and headward erosion was noticeable (Plates 14 and 15).

3) Between these two extremes another case was noticeable, which appeared to be created by enough moisture to make the surface layer (10 - 20 cm) "quick". This was probably augmented as well by rainfall directly on the surface; being more important on the side of the pile facing upwind during a particular storm event. The result was a "Translational" slip slope stability problem, which resulted in the equivalent of small mudflows moving down the side of the pile (Plate 13). Some had sufficient moisture to reach the asphalt. The movement created numerous small erosional rills over the side walls, starting at least part way down the slope. They were not associated with gullies commencing at the top of the slope.

However, these were formed only in certain areas of each side of the pile; the reason for which is unknown. The formation of non-circular slips is usually thought to occur where the form of the failure surface is influenced by the presence of an adjacent stratum of significantly different strength.

Translational slips tend to occur where the adjacent stratum is at a relatively shallow depth below the surface of the slope; the failure surface tends to be planar and roughly parallel to the slope. This suggests that the extremely loose portions of the side slopes are found within the top 0.3 m of the surface.

That component of q_o, which was directed longitudinally over the Coal Core HU, to either end of the pile, appeared to remain as Horton flow, due to: 1) the compactness (and therefore low permeability), of the surface, 2) the resultant lack of any

interflow zone, and 3)the relatively steep slopes. Numerous erosional gullies could usually be found over the ends of the piles(plate 16); the extent of which appeared to be due to at least the amount/intensity of rainfall received, and the compactness/slope of the surface.

It is hypothesized that runoff directed over the "off-ramp" end of the piles could more easily infiltrate, due to visually less compaction of the surface, than flow over the "on-ramp".

Infiltration Capacity and volume should theoretically increase over the ends of the pile, in those areas where deep erosional gullies have been dissected by concentration of overland flow (Plate 16). This allows surface runoff to reach into the lower level of the piles and pond in small bench cuts formed in the base of the gullies; the latter creating localized pressure-focused-recharge zones. As well, the concentration of flow and infiltration in these localized zones would create a higher probability that field moisture capacity would be achieved.

5.5 Vadose Zone Subsystem

The groundwater head data obtained from the monitoring wells indicated that only a minimum saturated thickness was present in the piles. Pile No 1 exhibited the maximum thickness of saturation of 10% of the total height of the pile at the centre line. Therefore the Vadose Zone makes up the largest portion of the coal piles. This Subsystem was not instrumented, given the method of approach set out in Section 1.3.

The key to understanding the percolation of any infiltrating water f, is the regulator within this subsystem, namely Field Capacity (M).

The input moisture content of the coal as it was added to the pile (Z) was monitored by CBDC personnel, and is a function of operations within the Preparation Plant itself, as well as additional moisture added directly to the pile for dust suppression during the summer months. Visual inspection of the piles after spraying suggests that this is not a major component of Z. The lowest attainable value from the plant is approximately 3%. The values obtained for Pile 1 had a mean value of 8.61% with a range(n=6) of 6.4 to 9.8%. Pile 4 had an input moisture from one sample of 8.43%.

To initiate infiltration of water through the Vadose zone requires that moisture content achieve field moisture capacity, before gravity drainage will take place. If the Z value exceeds field capacity, then natural gravity drainage will occur, allowing infiltrating water to reach the water table. If the value is lower than field capacity, then additional moisture from infiltrating rain waters will be added to storage within the vadose zone (L), thereby increasing the moisture content of the pile, until M is achieved.

Theoretical, calculations of moisture content at saturation were based upon specific gravities of 1.36 (thermal) and 1.29 (met), as well as unit weights of 1050 - 1220 Kg/m^3. These indicated a range from 15% - 32%. Moisture contents derived from split spoon samples in Piles 1 and 2 at the top of the asphalt, and therefore in the saturated zone, indicated moisture contents fluctuating from 9 -12%. However, moisture contents at the same position within Piles 3 and 4, in which piezometers remained consistently dry, had values ranging from 10 - 16%. What still remains open for speculation in utilizing moisture contents from the split spoon samples is, that given the large relative density values, a lot of friction was created in driving the spoon; which a number of times then came to the surface hot. This may have driven some of the moisture off prior to sampling.

Field capacities could theoretically be in the 10 - 20% range. Both of these ranges will change with density, which alters considerably throughout the pile, due not only to compaction by vehicles, but also the surcharging factor. Therefore given the higher densities with depth it is expected that percent for saturation should be at a minimum at the base of the core of the pile.

The split spoon samples collected during drilling of the piles indicated:

Pile 1: mean of 8.87%; range 4.0 - 12%;(n=42)
mean moisture of coal going into pile 8.61%
mean moisture of coal lifted from bank 8.53% (n=6)

Pile 2: mean of 9.74%; range 8.02 - 12.5% (n=33)
mean moisture of coal lifted from bank 9.64%(n=2)

Pile 3: mean of 6.31%; range 2.44 - 10.98% (n=30)
mean moisture of coal lifted from bank 8.62% (n=2)

Pile 4: mean of 8.15%; range 5.7 to 16.18% (n=42)
mean moisture of coal lifted from bank 8.68% (n=2)

These values are regarded as "Total" moisture derived from heating the sample at 105 ^{0}C until a constant weight is achieved. Therefore this includes both adsorbed (inter) and absorbed (intra) water. This is also referred to as the free, or air dry moisture versus the inherent or residual moisture. For the Lingan and Phalen Colliery coals dealt with in this study, an accepted value for the intra water is 1%.

Therefore, it would appear that if the theoretical ranges are valid for field moisture capacity, then only at localized points within the pile is M ever achieved. For a further discussion of infiltration during rainfall and recession events, note the discussion of water table fluctuations within Section 5.6.

The moisture profiles developed within the piles, as determined from split spoon samples, indicated that in Pile 1, PN 1 and 4, positioned along the mid line of the pile within the compacted core, exhibited low values near the surface, with a general fluctuating increase with depth; although PN 5 remained relatively consistent with depth. For PN 2 and 3 along the edges of the compacted core, one showed a rising trend with depth; the other a fluctuating trend with depth. Therefore no consistent pattern was found throughout the pile. This inconsistency was also present in the other piles monitored.

The thermocouples installed in Piles 3 and 4 indicated that in Pile 3, core temperatures near the base, at the centre, and outside edge of the pile remained consistently between 0 - 5^{0}C (6 - 7 m depth). From 1 - 5 m depth, temperatures ranged from 2 - 10^{0}C. At one hole there was a consistently elevated temperature of 10^{0}C at 1.5 m above the asphalt (5.8 m below surface). During the monitoring period the mean monthly air temperature was -4.6^{0}C (March).

In Pile 4 core temperatures near the base of the centre of the pile remained in the 8 - 9^{0}C (12.65 m depth). From 11.3 - 6.55 m below the surface of the pile, in the centre core the temperatures remained consistently at 10 - 12^{0}C. Mean monthly air temperature over this period ranged from 14.9^{0}C (June), to 3.9^{0}C (November).

These values were not sufficiently elevated enough to create evaporation of moisture within the pile (e_i).

The value of 10^{0}C is approximately twice the mean annual air temperature for the region; values of 6 - 10^{0}C approximates normal groundwater temperatures within the bedrock in the region.

One component of the Vadose Zone, not shown on Figure 5 - 1, but which may play a role in understanding the infiltration process, is gas pressure; resulting from the degassing of methane from the coal. This would certainly have a significant role in water chemistry in terms of oxidation, and the resultant development of acidic drainage.

5.6 Groundwater (Saturated) Zone Subsystem

This subsystem was monitored through the use of piezometers, and field inspections of the seepages out of the side of the piles, under varying weather conditions.

The monitoring well data indicated generally a very minimal thickness for the saturated zone within the piles. The largest/consistantly height monitored was 0.5 - 0.7 m above the asphalt base within Pile No 1. Utilizing grain size curves, the capillary fringe could theoretically extend upward an additional 0.1 to 0.25 m. Therefore the maximum measured height of the saturated zone/capillary fringe formed only some 10% of the total height of the pile at the centre line.

Fluctuations in water table elevations recorded in the piezometers were inconsistent with rainfall events (note Drawing 01 - in pocket at back). Given the small range in fluctuation it is expected that gas pressure changes in the Vadose zone due to barometric changes, compression from infiltration events, and methane degassing may also have an impact.

In developing the equipotential contours throughout the pile, (as has been done for Pile 1 - Drawing 01), the assumption was made of continuity. Three problems must be recognized in this regard:

1) As has been suggested by Ripp, infiltrating waters may not descend uniformly throughout a pile; but instead concentrate in infiltration zones created

typically by eroded gullies and uncompacted side slopes. Therefore it is not absolutely certain as to whether the saturated zones found at each piezometer are continuous or localized.

2) A further difficulty arose as a result of the thin saturated zone. Since it was impossible to drill into the asphalt in order to set the bottom of the piezometer tip below the surface of the asphalt, a saturated zone of less than a couple of centimetres would not show up in the piezometer.

3) If the assumption of a homogeneous, isotropic medium is not valid in the microscale within the pile, than the level-of-effort applied to instrumenting the pile with piezometers, would be inadequate to give an exact appreciation of the lateral extent of saturated flow within the pile.

These three concerns were supported by data interpretation and field inspections which noted the position, nature, and duration of seepages. Groundwater was noted seeping out of the toe of the slope, but only at localized areas during certain time periods. The nature of these seepages is best characterized by the instrumentation/ observations/photographs taken during the monitoring of Pile 1. Pertinent points include:

1) All noticeable seepages originated out of the sides, not the ends of the pile. This was believed to be a function of the grading on the asphalt surface, coupled with the greater compaction of the ends due to vehicular traffic.

2) There were no perched water tables in evidence in any of the piles, as determined by the absence of wet areas or springs over the side slopes (Plates 2 and 18).

3) All seepages were noted discharging out from the toe of the side slopes, either as actual water, or a darker damp zone in contrast to the lighter drier upper slopes (Plate 18).

4) Drawing 01 defines the water table surface within Pile 1, based upon piezometer installations, as well as the visual observations made concerning the locations of toe seepages for the period July 31, 1989 to August 2, 1989. The data clearly notes that the region of the pile, where the piezometers recorded the thickest saturated zone (north end at PN 4), does not give any evidence of toe seepage.

However, most of the seepage was noted discharging out of both sides of the south end of the pile opposite PN 5, where the saturated zone was the thinnest.

On August 2, 1989 at 6 a.m., the west side of the pile exhibited a 100 m long active seepage zone (Plate 17). The remainder of this side can be characterized as dry with sporadic damp areas. On the east side of the pile the longest seepage zone is 30 m long (Plate 18), with two very localized discharges in close proximity to PN 6 even though that piezometer was dry. Excavating into the toe of the bank indicated an actual saturated zone of 1-2 cm in thickness.

Of interest was that a diurnal variation in the seepage was also noticeable, such that by 2 p.m. on the same day (August 2, 1989) all toe seepage had dried up, due to the hot summer day (Plate 19). At 6 a.m on August 3rd, the seepages noted on the previous morning were again present. This indicates that during hot days the loss of water by evaporation directly from the saturated zone (e_s) does occur near the outer edges of the pile.

5) The water table elevations also indicate that the high point at PN 4 did not correspond with the highest topographic area, such as would be expected in a true homogeneous, isotropic media. However, it was positioned under the area which was likely compacted the most. The result theoretically would

have been a reduced porosity, therefore a lower percent saturation, but also a reduced hydraulic conductivity. This should result in the elevated water table and reduced flow rates noted.

6) Inspection of Pile 3 during the winter months of 1990 indicated that a damp capillary fringe was present at certain times in localized areas; but no water was actually seen discharging (that could be attributable to groundwater flow, not snowmelt). However, upon excavating into the toe of the slope, a layer of ice was noted a couple of centimetres thick. It is therefore hypothesized that during the winter months the slow seepage out of a thin saturated zone was quickly frozen as it reached the outer edge of the pile.

7) An analysis of the water level data obtained from the piezometers indicated the following pertinent points.

- At the transverse cross section the three piezometers indicated a higher elevation in the water table on the west side of the pile at PN 3, than in the centre, where it would be expected. If this holds true for the entire length of the pile, it would account for the greater amount of seepage noted out of the west side of the bank. However the reason for such an anomaly is unknown.
- PN 5 went dry by late July, yet seepage was still noticeable out of both sides of the pile in early August (Plates 17 and 18).
- There is no significant response to any of the eight rainfall events which occurred during the monitoring period, except for the rainfall received during August 6,7,8 (total of 6.4, 1.8, and 18.4 mm respectively). Yet even then PN 5 showed no rise. PNs 1,2,3 and 4 showed slight rises of 1 to 2 cm on August 8. Further, PN 2, for no apparent reason, exhibited a significant rise in level of almost 20 cm on August 9, when all other piezometers showed a recessional trend.

- There is no consistent correlation between atmospheric pressure and water levels; however unsaturated zone methane gas pressures may have been influencing the trend.

Pile No. 2 also provided evidence of a thin (0.2 - 0.4 m) consistant saturated zone, which exhibited only minor water level fluctations.

Piles 3 and 4 were noteworthy in their absence of any saturated zone, even though rainfall during the fall of 1990 was significant.

6.0 RECOMMENDATIONS TO CONTROL MOISTURE IN COAL PILES

Based upon the data collected, and the conceptual model of the hydrologic cycle developed for the piles, certain recommendations can be made regarding the control of water in the piles.

1) The volume of precipitation (P) landing on the piles could be reduced by:
   - constructing the piles so as to achieve the maximum heights possible over the smallest area,
   - constructing and removing the piles as quickly as possible.

   These methods should be considered to be more imperative for those piles which will be degassing during the late fall/winter season; especially the later (October to December), since this is the time of greatest precipitation, and the period when the trend of increasing rainfall is being felt.

   One potential method would also be to enhance methane degassing by vapour extraction, in order to reduce the length of time the piles need to be exposed to the atmosphere. However this would entail additional study and cost/benefit analysis.

2) An attempt should be made to reduce the incoming moisture (Z) created by the preparation plant process itself.

3) The volume of precipitation which infiltrates into the pile could be reduced by attempting to reduce F (infiltration capacity) and R (surface storage) while increasing q_o (surface runoff). This could be accomplished by:

A) compacting the surface (including side slopes) in order to reduce infiltration and increase runoff through the use of:

- rubber-tyred vehicles wherever possible
- special rollers for the side slopes
- utilizing alternate ends of the pile for bringing loaded coal trucks onto the pile
- possible addition of a final cover of very fine coal and compacting it with a roller,

B) creating a convex longitudinal slope without a flat topped centre section, in order to increase the rate of runoff,

C) creating a concave cross sectional profile over the top of the pile in order to direct surface runoff away from the less compacted sides, and toward the more highly compacted centre

D) keeping longitudinal slopes as steep and as smooth as possible to enhance surface runoff, and eliminate any ponding, yet still allowing vehicular access,

E) removal of the pile only from the base, not the top, since the latter only opens up new (usually) drier parts of the pile to rainfall.

F) filling in erosional gullies as soon as noticed, to reduce infiltration

4) For the water that does infiltrate into the Vadose Zone of the pile, it will be necessary to increase D (deep percolation) by creating a reduction in M (field moisture capacity). This would then allow a smaller volume of infiltration to be required in order to allow for rapid gravity drainage down

to the saturated zone. This would have to be achieved by altering grain size, porosity and density factors. How viable this is, given operational constraints, is unknown.

It must be realized that other concerns regarding quality of the product, other than moisture percentage, must be accounted for at this stage as well. This is exemplified by taking the above action to the extreme, through the use of radial arm stackers to construct the piles in a loose form. This would speed up the infiltration rate through the vadose zone. However the resultant more open structure would also allow greater diffusion of oxygen into the pile, which would in turn reduce the quality of the product, (specifically its fluidity), as well as enhance the formation of acid drainage.

5) For that water that does infiltrate through the Vadose Zone and down to the saturated zone, it will be necessary to increase the rate of groundwater discharge (g) out of the pile. Depending upon operational difficulties this might be accomplished by putting down a coarse layer of coal with a higher hydraulic conductivity at the base of the pile, and perhaps half way up the pile to act as a drain. The success of such a modification should be confirmed by modelling.

6) Theoretical considerations indicate that one way to reduce moisture on top, or within the pile, would be to spread the pile out over a larger area in order to increase evaporation loses. However, this would increase the surface area allowing more precipitation to land on the pile (note point 1 above). The latter is considered to be more important to control, and therefore this technique is not recommended. Operational difficulties preclude this as well.

LIST OF REFERENCES

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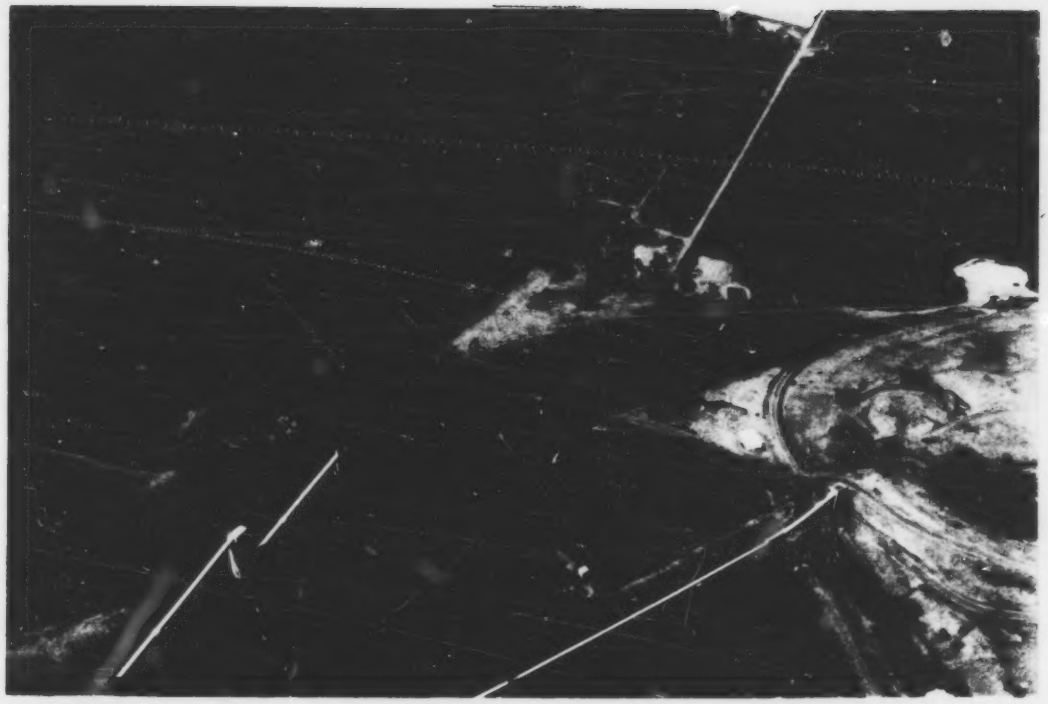
Ripp, J., 19??. Understanding Coal Pile Hydrology Can Help BTU Loss in Stored Coal TRC, Environmental Consultants.

Toth, J., 1970. A Conceptual Model of the Groundwater Regime and the Hydrologic Environment Contribution. 461. Alberta Research Council, Edmonton, Alberta.

APPENDIX 1

PLATES

PLATE # 1



Overview of the Lifting Banking Centre, August 24, 1990 during the monitoring of Pile No. 4 (upper left corner).

PLATE # 2

A view of Pile No. 4, July 11, 1990 during the degassing period. The pile is approximately 275 m long, 45 m wide, and 15 m high. Note the loose side slopes and moderately compacted material over the "off-ramp" end.

PLATE # 3

Pile No. 1 under construction. Note dumping method and compacted surface.

PLATE # 4

Pile No. 1 under construction. Note method of spreading coal "windrows" and resultant loose side slopes

PLATE # 5

Pile No. 4 after construction. Note flat top with compacted centre and less compacted sides. Also shown are the 3 piezometer locations across the centre line of the pile.

PLATE # 6

Removal technique for Pile 1 by excavating from the base of the side walls. Note compacted core standing vertical.

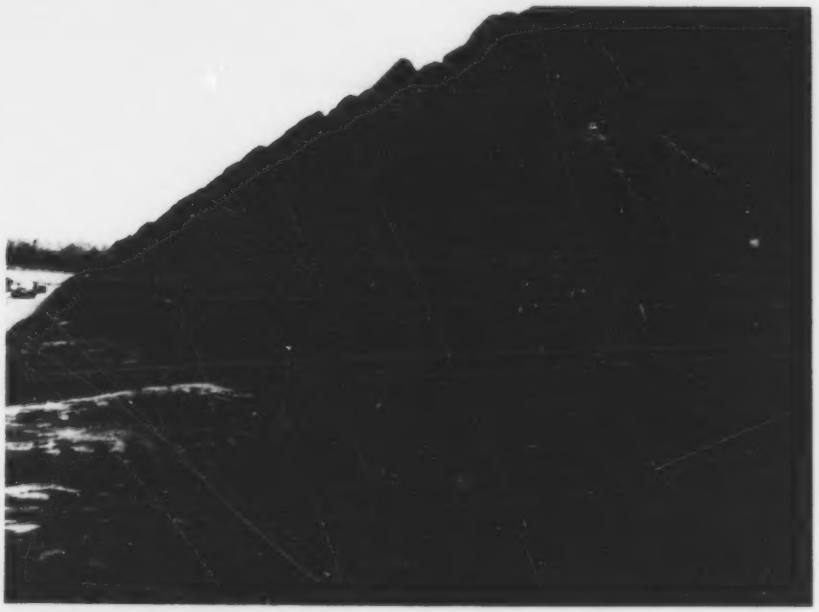


PLATE # 7

Removal technique for Pile 1. Material is also being excavated off the top of the pile and pushed over the edge

PLATE # 8

Pile 1 during excavation. Note layered heterogeneity in the compacted core of the pile.

PLATE # 9

Pile 1, June 20, 1989; Class 1 type surface: heavily compacted over "on-ramp".

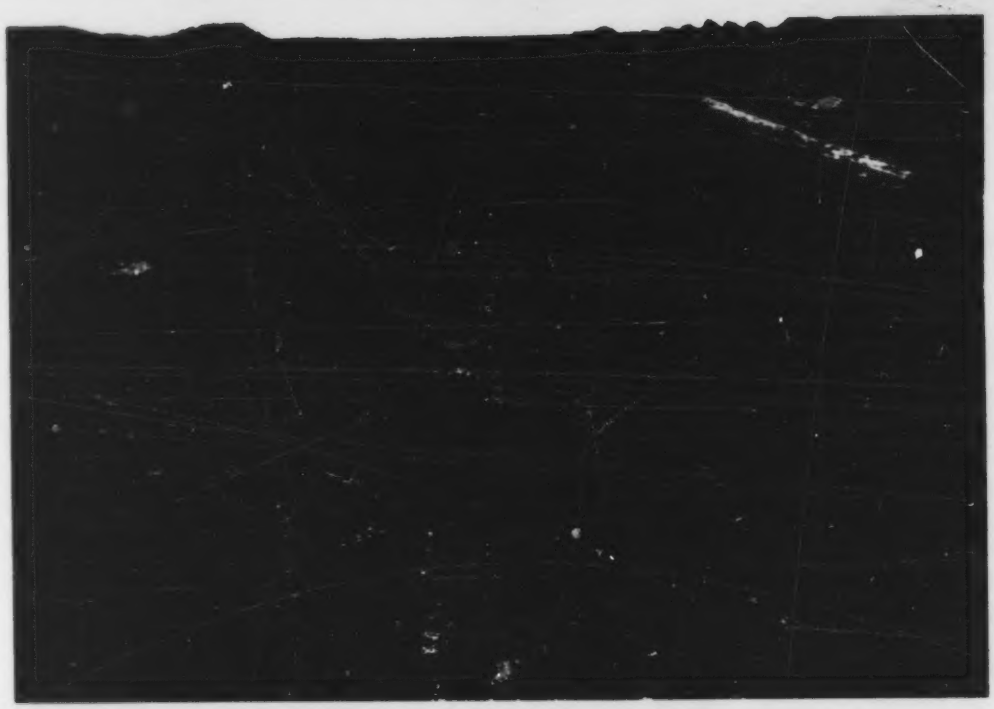


PLATE # 10

Pile 1, July 10, 1989; Class 2 type surface: moderately compacted, note footprints.

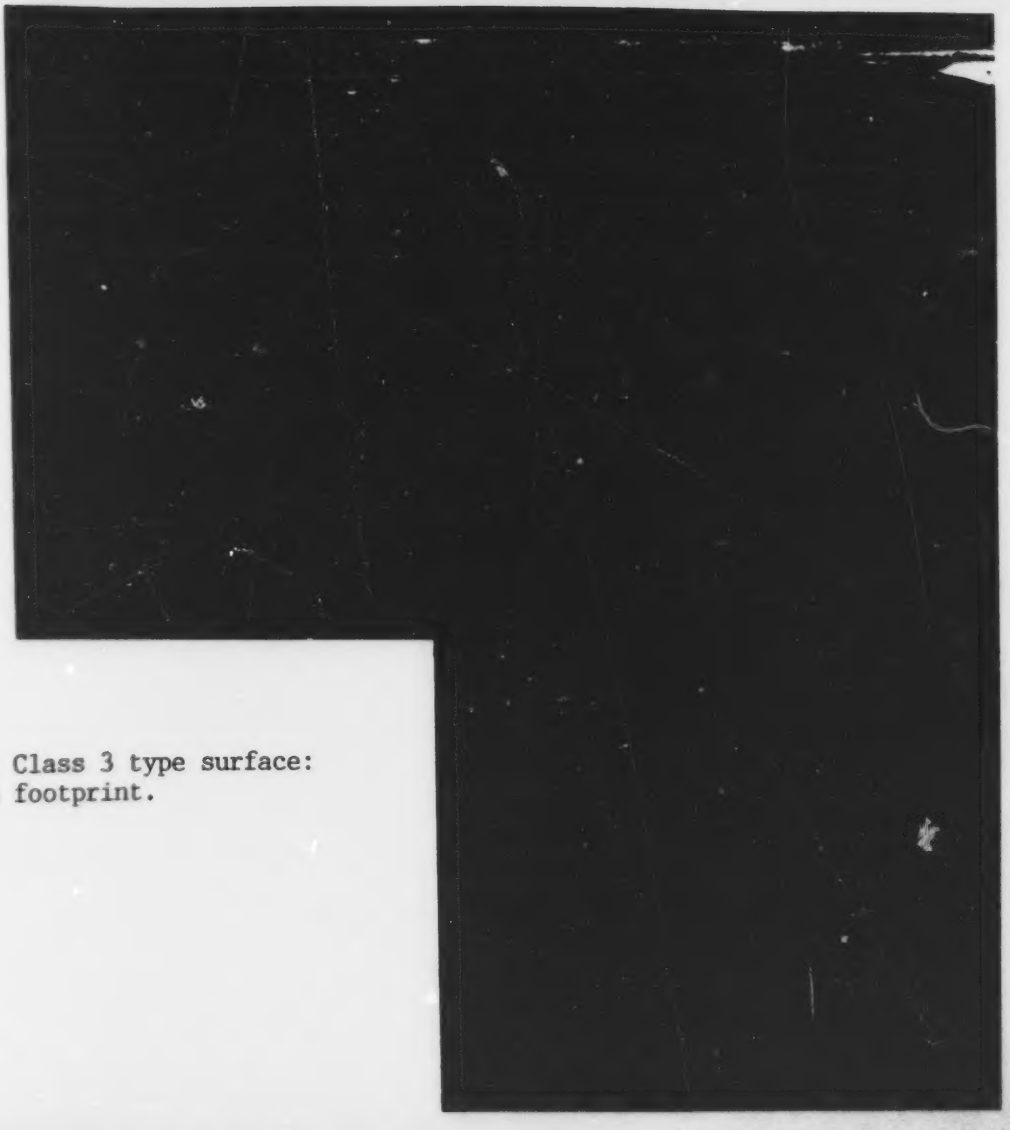


PLATE # 11

Pile 1, June 14, 1989; Class 3 type surface: loose over sides, note footprint.

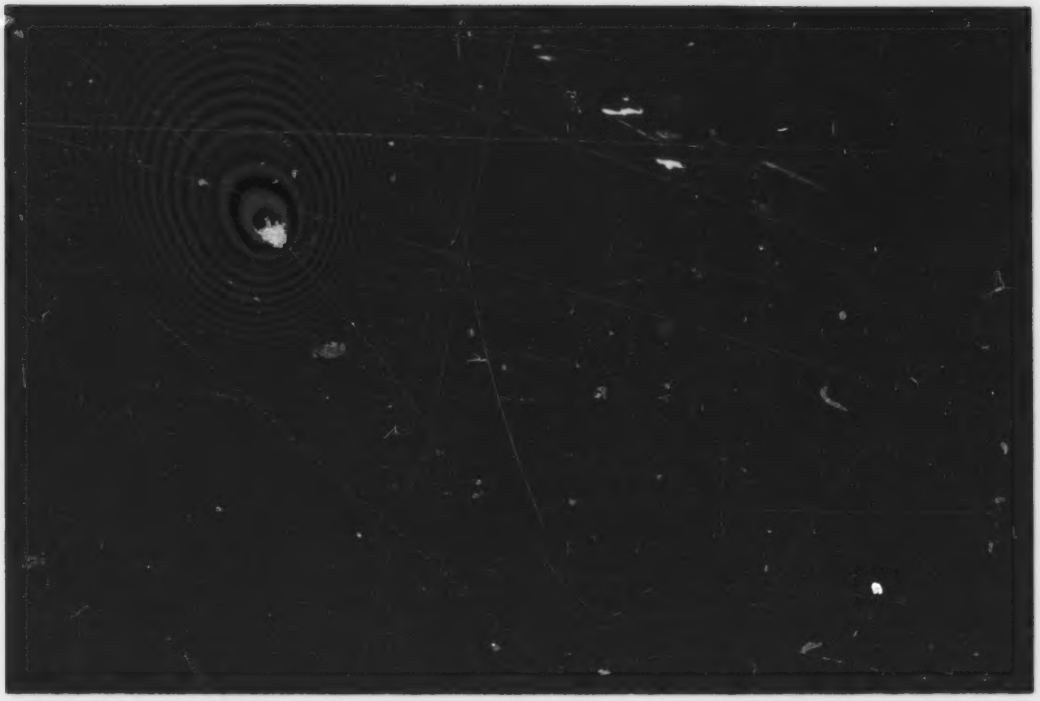
PLATE # 12

Pile No. 4 on August 1, 1990 at 7:30 p.m. during Huricane Bertha. Note overland flow both longitudinally and laterally across the surface.

PLATE # 13

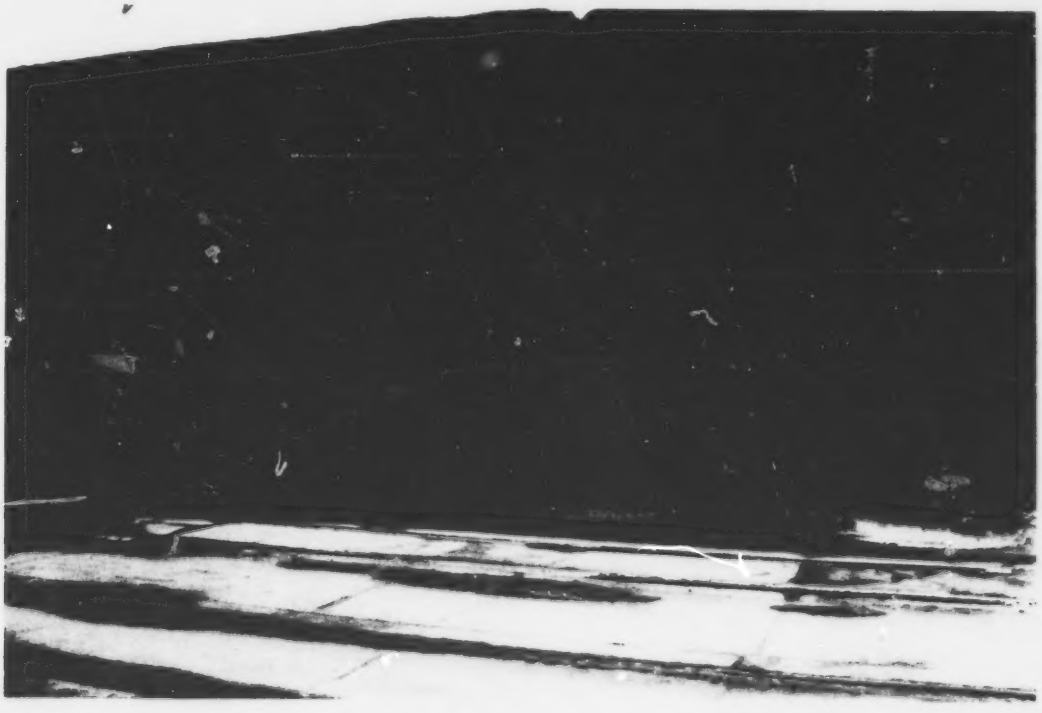
Pile No. 4 on August 3, 1990. Note "Translational Slip" type erosional features and resultant "mudflow" type transport.

PLATE # 14



Pile No. 4, August 3, 1990 after Huricane Bertha. Note gullying on the top of the pile has directed surface runoff laterally over the side.

PLATE # 15



Pile No. 4. Gulling developed downgradient of gully, shown in Plate # 14 above. Also note rills developed from "mudflow" type transport.

PLATE # 16

Pile No. 4 mid August.
Note extent and development
of gullying over "on-ramp"
end of pile.

PLATE # 17 - PILE No. 1

Seepage out of west side August 2, 1989 at 9 a.m. looking north. Note absence of perched water tables

PLATE # 18- Pile No. 1

Seepage out of east side August 2, 1989 at 9 a.m. looking north. Note absence of perched water tables.

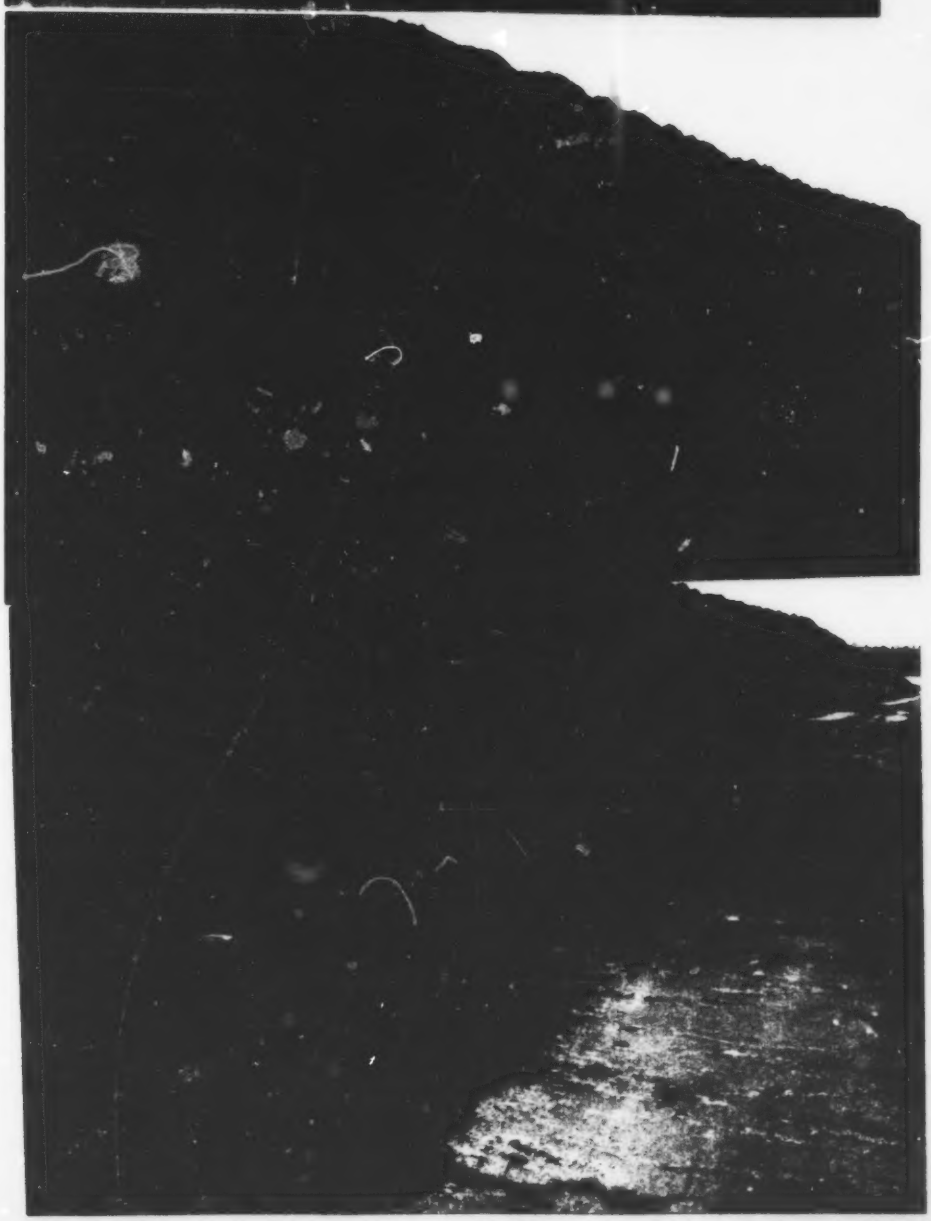


PLATE # 19 - Pile No. 1

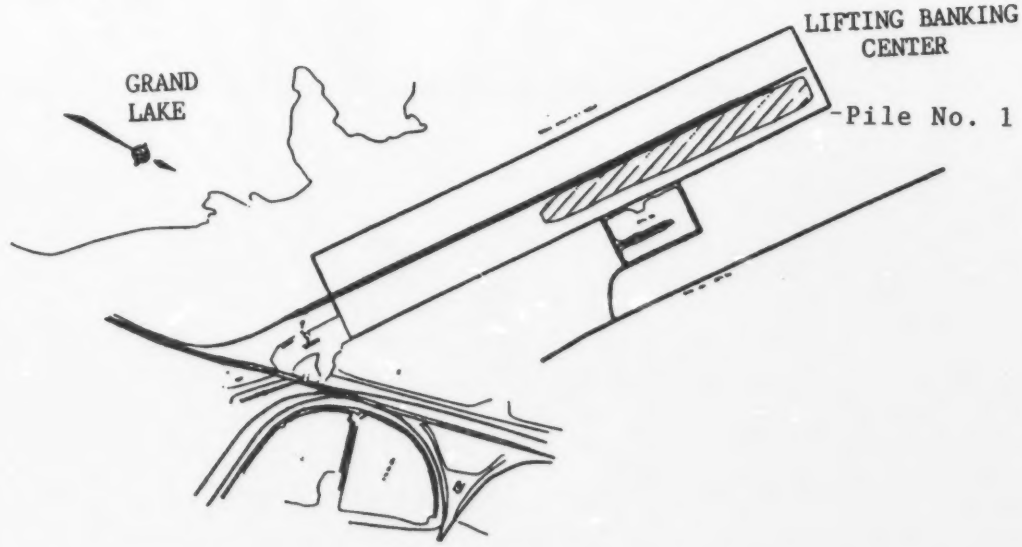
Note absence of seepage out of east side, August 2, 1989 at 2 p.m. looking north.

APPENDIX 2

PERTINENT DATA FOR PILE NO. 1
NO. 65 THERMAL BANK OPERATIONAL PERIOD:
JUNE TO SEPTEMBER 1989

LOCATION MAP

KEY PLAN
SCALE 1:10,000



NOTE: Piezometer locations and numbering are noted on Drawing 01 (in pocket at back).

STOCKPILE HYDROLOGY STUDY
#65 THERMAL BANK JULY/AUGUST 1989 - Water Table Elevations

ELEVATION OF WATER IN METERS (FROM SEA LEVEL)

DATE	TIME	HOLE # 1	HOLE # 2	HOLE # 3	HOLE # 4	HOLE # 5	HOLE # 6	HOLE # 7
89-07-27	17:00	33.32	DRY	DRY	--	--	--	--
89-07-28	09:00	33.56	33.47	33.49	--	--	DRY	--
89-07-28	14:00	33.57	33.49	33.53	--	--	--	--
89-07-28	15:30	33.58	33.51	33.54	DRY	DRY	DRY	DRY
89-07-31	09:05	33.52	33.47	33.67	33.95	33.38	DRY	DRY
89-07-31	12:00	33.52	33.47	33.67	33.95	33.35	DRY	DRY
89-08-01	10:20	33.52	33.47	33.67	33.95	33.35	DRY	DRY
89-08-02	11:15	33.52	33.49	33.67	33.95	33.32	DRY	DRY
89-08-03	12:05	33.52	33.49	33.68	33.96	33.30	DRY	DRY
89-08-04	10:08	33.52	33.49	33.65	33.93	33.29	DRY	DRY
89-08-07	09:50	33.52	33.47	33.62	33.90	DRY	DRY	DRY
89-08-08	08:45	33.53	33.48	33.62	33.91	DRY	DRY	DRY
89-08-08	12:00	33.51	33.46	33.61	33.89	DRY	DRY	DRY
89-08-09	08:20	33.48	33.65	33.51	33.85	DRY	DRY	DRY
89-08-10	08:15	33.43	33.56	33.56	33.82	DRY	DRY	DRY
89-08-11	08:20	33.44	33.56	33.56	33.82	DRY	DRY	DRY
89-08-14	08:15	33.43	33.56	33.55	33.81	DRY	DRY	DRY
89-08-15	08:55	33.43	33.55	33.54	33.80	DRY	DRY	DRY
89-08-16	10:20	33.42	33.54	33.53	33.78	DRY	DRY	DRY
MEASURED DEPTH		--	33.43	33.14	33.29	33.19	33.42	32.93
TOP OF PIPE		43.62	41.96	41.82	41.60	40.13	37.09	36.58
TOP OF COAL		41.90	41.84	41.61	41.44	39.90	35.72	35.39
FLOOR*		33.65	33.58	33.61	33.37	33.75	33.46	33.54
FLOOR@		33.66	33.67	33.60		33.75	33.46	33.46

*Calculated by interpolation of elevations determined when built
@ Field measurements after removal of pile, October 1989

(Courtesy CBDC)

STOCKPILE HYDROLOGY STUDY
#65 THERMAL BANK JULY/AUGUST 1989

TOTAL MOISTURE CONTENT OF SPLIT SPOON SAMPLES (%)

SAMPLE #	HOLE # 1	HOLE # 2	HOLE # 3	HOLE # 4	HOLE # 5	HOLE # 6	HOLE # 7
1	5.0	8.3	4.0	4.9	10.0		
2	5.3	5.6	8.7	10.4	8.5		
3	8.0	8.6	7.5	7.8	10.5		
4	9.3	9.2	9.8	8.7	8.7		
5	8.4	9.5	8.5	9.6	9.9		
6	10.1	9.4	12.6	11.7			
7	11.1	9.9	12.0				
8	5.9	7.6					
9	7.6	8.5					
10	8.2	9.6					
11	9.6	10.6					
12	8.9	9.2					

(Courtesy CBDC)

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-1JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #1 - #85 THERMAL BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 07/24/89 -	ELEVATION 41.90 (m)

SAMPLE TYPE ■ ◪ ☒ SPLIT SPOON ▤ ▥ ▦

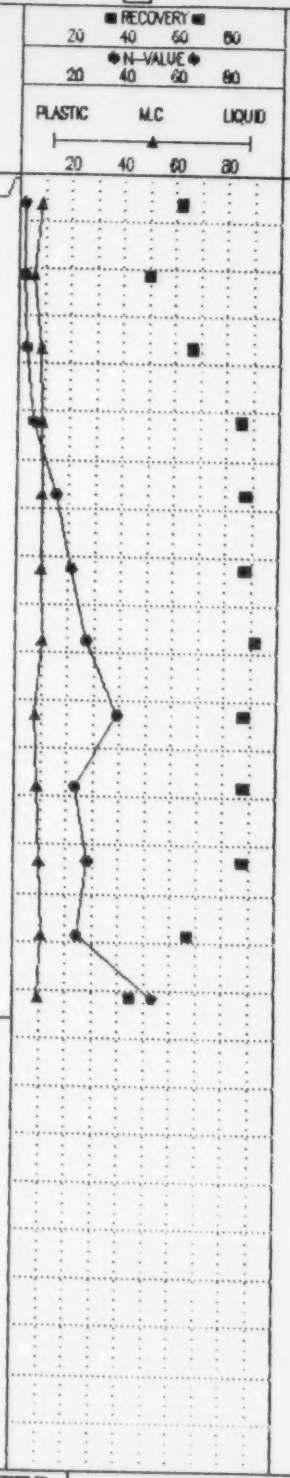
DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION 41.9m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0	☒	2					1.0
2.0	☒	3					2.0
	☒	4					
3.0	☒	5					3.0
4.0	☒	6					4.0
5.0	☒	7					5.0
	☒	8					
6.0	☒	9					6.0
7.0	☒	10					7.0
8.0	☒	11					8.0
	☒	12					
9.0			END OF BOREHOLE AT 8.80m. AT TOP OF ASPHALT. ELEVATION 33.1m.				9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 8.8 m		COMPLETE 07/24/89
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-2JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #1 - #85 THERMAL BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 07/24/89 -	ELEVATION 41.80 (m)

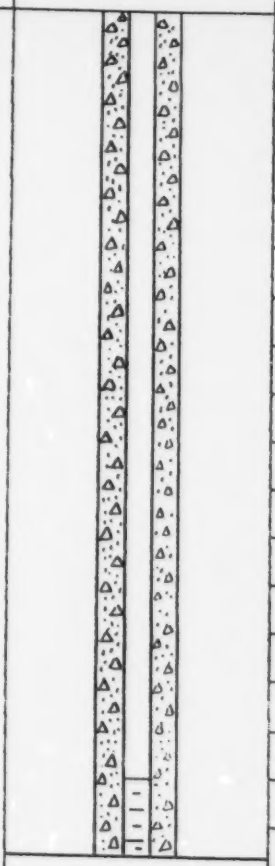
SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▥

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION
0.0		1	COAL SURFACE ELEVATION 41.8m.
			COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.
1.0		2	
2.0		3	
3.0		4	
		5	
4.0		6	
5.0		7	
		8	
6.0		9	
7.0		10	
8.0		11	
		12	
8.8			END OF BOREHOLE AT 8.80m.
			AT TOP OF ASPHALT. ELEVATION 33.0m.
10.0			
11.0			
12.0			
13.0			



USC

PIEZOMETER INSTALLATION



DEPTH (m)

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 8.8 m		COMPLETE 07/24/89
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-3JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #1 - #85 THERMAL BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 07/27/89 -	ELEVATION 41.60 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION 41.6m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
8.0	☒	6					8.0
	☒	7	END OF BOREHOLE AT 8.60m. AT TOP OF ASPHALT. ELEVATION 33.0m.				
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 8.6 m	COMPLETE 07/27/89	
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-4JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #1 - #85 THERMAL BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 07/27/89 -	ELEVATION 41.40 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▮▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION 41.4m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
8.0	☒	6	END OF BOREHOLE AT 8.00m. AT TOP OF ASPHALT. ELEVATION 33.4m.				8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 8.0 m		COMPLETE 07/27/89
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-5JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #1 - #85 THERMAL BANK	Project No: 389-089
LONGYEAR DRILLING	START DATE: 07/27/89 -	ELEVATION 39.90 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▥

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION 39.9m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying comapctness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0			END OF BOREHOLE AT 6.71m. AT TOP OF ASPHALT. ELEVATION 33.2m.				7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 6.7 m		COMPLETE 07/27/89
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

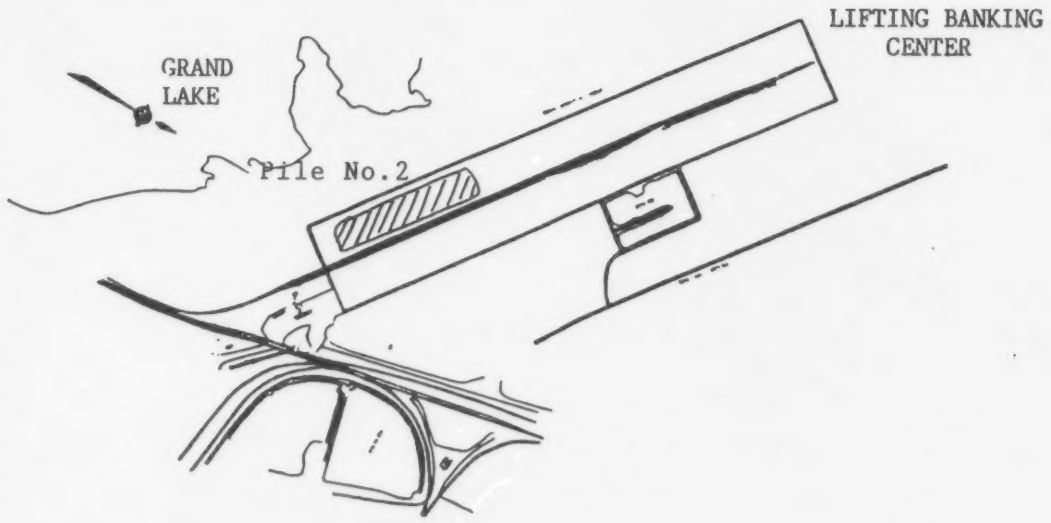
APPENDIX 3

PERTINENT DATA FOR PILE NO. 2
NO. 74 MET BANK OPERATIONAL PERIOD:
OCTOBER - NOVEMBER 1989

LOCATION MAP

KEY PLAN

SCALE 1:10,000



NOT DRAWN TO SCALE

NOLAN, DAVIS & ASSOCIATES

PILE NO. 2
LOCATION / NUMBERING OF PIEZOMETERS

STOCKPILE HYDROLOGY STUDY
#74 MET BANK OCTOBER/NOVEMBER 1989

Water Table Elevations

DEPTH IN METERS FROM TOP OF PVC PIPE (ACTUAL PIEZOMETER READINGS)

DATE	TIME	HOLE # 1	HOLE # 5	HOLE # 4	HOLE # 3	HOLE # 2	HOLE # 6
89-10-31	09:45	DRY	-7.655	DRY	DRY	DRY	DRY
89-11-02	08:45	DRY	-7.575	-7.972	DRY	-9.160	DRY
89-11-02	16:00	DRY	-7.880	-7.980	DRY	-9.175	DRY
89-11-03	16:00	DRY	-7.565	-7.955	DRY	-9.185	-2.520
89-11-04	00:30	DRY	-7.542	-7.962	DRY	DRY	DRY
89-11-04	11:30	DRY	-7.576	-7.981	DRY	DRY	DRY
89-11-04	23:00	DRY	-7.612	-7.994	DRY	DRY	DRY
89-11-05	14:30	DRY	-7.613	-8.001	DRY	DRY	DRY
89-11-06	13:30	DRY	-7.600	-8.010	DRY	DRY	DRY
89-11-07	08:45	DRY	-7.575	-8.000	DRY	DRY	DRY
89-11-07	12:45	DRY	-7.575	-8.000	DRY	DRY	DRY
89-11-08	13:00	DRY	-7.570	-8.005	DRY	DRY	DRY
89-11-09	12:45	DRY	-7.555	-8.005	DRY	DRY	-3.570
89-11-09	23:00	DRY	-7.635	-7.991	DRY	DRY	-3.565
89-11-10	08:45	DRY	-7.530	-7.980	DRY	DRY	-3.565
89-11-10	14:00	DRY	-7.530	-7.980	DRY	DRY	-3.565
89-11-11	11:30	DRY	-7.531	-7.969	DRY	DRY	-3.542
89-11-12	15:45	DRY	-7.507	-7.960	DRY	DRY	-3.531
89-11-13	09:45	DRY	-7.539	-7.979	DRY	DRY	-3.521
89-11-13	16:15	DRY	-7.545	-7.979	DRY	DRY	-3.519
89-11-14	17:30	DRY	-7.523	-7.970	DRY	DRY	-3.516
89-11-15	13:50	DRY	-7.528	-7.975	DRY	DRY	-3.507
89-11-16	08:30	DRY	-7.521	-7.967	DRY	DRY	-3.505
89-11-16	14:35	DRY	-7.516	-7.960	DRY	DRY	-3.505
89-11-17	08:30	DRY	-7.495	-7.948	DRY	DRY	-3.500

ELEVATION OF WATER IN METERS (FROM SEA LEVEL)

HOLE # 1	HOLE # 5	HOLE # 4	HOLE # 3	HOLE # 2	HOLE # 6
DRY	33.8v	DRY	DRY	DRY	DRY
DRY	33.97	33.75	DRY	33.86	DRY
DRY	33.67	33.74	DRY	33.84	DRY
DRY	33.98	33.77	DRY	33.83	34.51
DRY	34.01	33.76	DRY	DRY	DRY
DRY	33.97	33.74	DRY	DRY	DRY
DRY	33.94	33.73	DRY	DRY	DRY
DRY	33.94	33.72	DRY	DRY	DRY
DRY	33.95	33.71	DRY	DRY	DRY
DRY	33.97	33.72	DRY	DRY	DRY
DRY	33.97	33.72	DRY	DRY	DRY
DRY	33.98	33.72	DRY	DRY	DRY
DRY	33.99	33.72	DRY	DRY	33.44
DRY	33.91	33.73	DRY	DRY	33.47
DRY	34.02	33.74	DRY	DRY	33.47
DRY	34.02	33.74	DRY	DRY	33.47
DRY	34.02	33.75	DRY	DRY	33.49
DRY	34.04	33.76	DRY	DRY	33.50
DRY	34.01	33.74	DRY	DRY	33.51
DRY	34.00	33.74	DRY	DRY	33.51
DRY	34.03	33.75	DRY	DRY	33.52
DRY	34.02	33.75	DRY	DRY	33.53
DRY	34.03	33.76	DRY	DRY	33.53
DRY	34.03	33.76	DRY	DRY	33.53
DRY	34.05	33.77	DRY	DRY	33.53

ELEVATION OF WATER IN RELATION TO FLOOR (METERS) CALCULATED BY INTERPOLATION OF DRAWING ELEVATIONS

HOLE # 1	HOLE # 5	HOLE # 4	HOLE # 3	HOLE # 2	HOLE # 6
	0.174				
	0.254	0.200		0.149	
	-0.051	0.192		0.134	
	0.264	0.217		0.124	1.143
	0.287	0.210			
	0.253	0.191			
	0.217	0.178			
	0.216	0.171			
	0.229	0.162			
	0.254	0.172			
	0.254	0.172			
	0.259	0.167			
	0.274	0.167			0.093
	0.194	0.181			0.098
	0.299	0.192			0.098
	0.297	0.192			0.098
	0.298	0.203			0.121
	0.322	0.212			0.132
	0.290	0.193			0.142
	0.284	0.193			0.144
	0.306	0.202			0.147
	0.301	0.197			0.156
	0.308	0.205			0.158
	0.313	0.212			0.158
	0.334	0.224			0.163

ELEVATION OF WATER IN RELATION TO FLOOR (METERS) DETERMINED FROM ACTUAL MEASUREMENT OF FLOOR ELEVATION AFTER REMOVAL OF STOCKPILE

HOLE # 1	HOLE # 5	HOLE # 4	HOLE # 3	HOLE # 2	HOLE # 6
	0.245				
	0.325	0.264		0.190	
	0.020	0.256		0.175	
	0.335	0.281		0.165	1.150
	0.358	0.274			
	0.324	0.255			
	0.288	0.242			
	0.287	0.235			
	0.300	0.226			
	0.325	0.236			
	0.325	0.236			
	0.330	0.231			
	0.345	0.231			0.100
	0.265	0.245			0.105
	0.370	0.256			0.105
	0.370	0.256			0.105
	0.369	0.267			0.128
	0.393	0.276			0.139
	0.361	0.257			0.149
	0.355	0.257			0.151
	0.377	0.266			0.154
	0.372	0.261			0.163
	0.379	0.269			0.165
	0.384	0.276			0.165
	0.405	0.288			0.170

	HOLE # 1	HOLE # 5	HOLE # 4	HOLE # 3	HOLE # 2
MEASURED DEPTH	-7.759	N.D.	-8.127	-6.939	-9.269	-3.649
TOP OF PIPE	41.524	41.549	41.722	40.514	43.019	37.033
*TOP OF COAL						
BOTTOM OF HOLE	33.765		33.595	33.575	33.750	33.384
FLOOR	33.630	33.720	33.550	33.620	33.710	33.370
FLOOR§	33.547	33.649	33.486	N.D.	33.669	33.363

*Calculated by interpolation of elevations determined when built
§ Field measurements after removal of pile, DEC 15, 1989
PIEZOMETER ELECTRODE TO TIP LENGTH (METERS) 0.089 (3.5 INCHES)

TOTAL MOISTURE CONTENT OF SPLIT SPOON SAMPLES (%)

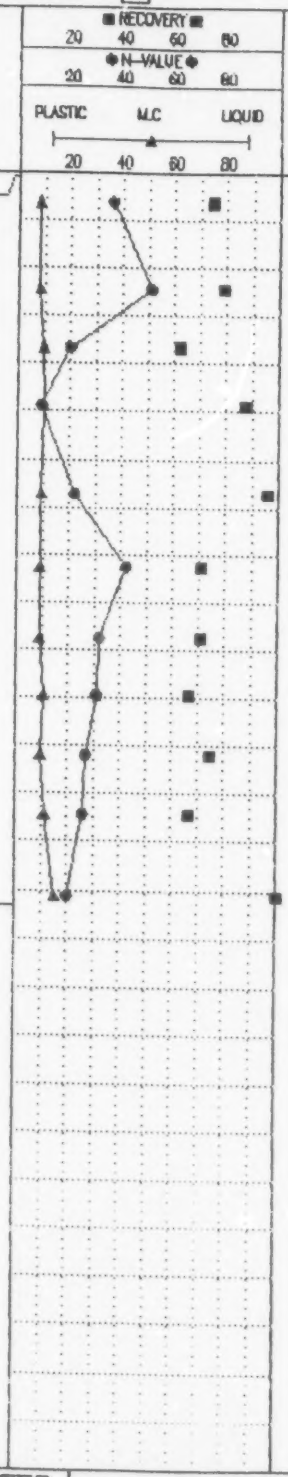
SAMPLE #	HOLE # 1	HOLE # 5	HOLE # 4	HOLE # 3	HOLE # 2
1	8.16	8.72	9.76	8.37	8.06
2	8.02	9.57	10.41	9.05	10.12
3	9.79	8.92	9.47	8.35	8.33
4	10.06	9.85	9.32	10.10	9.07
5	9.16	9.57	14.43	10.32	10.02
6	8.93	11.97	10.73		10.06
7	9.01				12.50
8	10.57				
9	9.58				

(Courtesy CBDC)

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-10CT
VICTORIA JUNCTION PREPARATION PLANT	PILE #2 - #4 WET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 10/30/89 -	ELEVATION 41.44 (m)

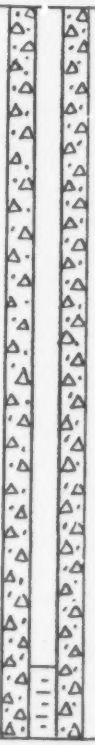
SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION
0.0	▨	1	COAL SURFACE ELEVATION 41.44m.
1.0	▨	2	COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.
2.0	▨	3	
	▨	4	
3.0	▨	5	
4.0	▨	6	
	▨	7	
5.0	▨	8	
	▨	9	
6.0	▨	10	
7.0	☒	11	
7.67			END OF BOREHOLE AT 7.67m. AT TOP OF ASPHALT. ELEVATION 33.77m.
8.0			
9.0			
10.0			
11.0			
12.0			
13.0			



USC

PIEZOMETER INSTALLATION



DEPTH (m)

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 7.7 m	COMPLETE 10/31/89	
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-20CT
VICTORIA JUNCTION PREPARATION PLANT	PILE #2 - #4 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 10/30/89 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▯ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0	☒	6					7.0
7.62			END OF BOREHOLE AT 7.62m. AT TOP OF ASPHALT. ELEVATION				
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 7.6 m		COMPLETE 10/30/89
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-30CT
VICTORIA JUNCTION PREPARATION PLANT	PILE #2 - #74 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 10/30/89 -	ELEVATION 41.37 (m)

SAMPLE TYPE ■ ◪ ☒ SPLIT SPOON ☰ ▯ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION 41.37m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
7.7	☒	6	END OF BOREHOLE AT 7.77m. AT TOP OF ASPHALT. ELEVATION 33.60m.				8.0
8.0							
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 7.8 m		COMPLETE 10/30/89
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-40CT
VICTORIA JUNCTION PREPARATION PLANT	PILE #2 - #74 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 10/30/89 -	ELEVATION 40.29 (m)

SAMPLE TYPE ■ ⊘ ⊠ SPLIT SPOON ☰ ▯ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	⊠	1	COAL SURFACE ELEVATION 40.29m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	⊠	2					2.0
3.0	⊠	3					3.0
4.0							4.0
5.0	⊠	4					5.0
6.0	⊠	5					6.0
7.0			END OF BOREHOLE AT 6.71m. AT TOP OF ASPHALT. ELEVATION 33.58m				7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 6.7 m		COMPLETE 10/30 89
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 89-50CT
VICTORIA JUNCTION PREPARATION PLANT	PILE #2 - #4 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 10/30/89 -	ELEVATION 42.52 (m)

SAMPLE TYPE ■ ☒ SPLIT SPOON

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	USC	PIEZOMETER INSTALLATION
0.0	☒	1	COAL SURFACE ELEVATION 42.52m. COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.		
1.0					
2.0	☒	2			
3.0	☒	3			
4.0					
5.0	☒	4			
6.0	☒	5			
7.0					
8.0	☒	6			
9.0	☒	7	END OF BOREHOLE AT 9.14m. AT TOP OF ASPHALT. ELEVATION 33.38m.		
10.0					
11.0					
12.0					
13.0					

■ RECOVERY ■ 20 40 60 80
● N-VALUE ● 20 40 60 80
PLASTIC M.C LIQUID 20 40 60 80

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 9.1 m	COMPLETE 10/30/89
	LOGGED BY O.R. N.B	DWG NO.1
		Page 1 of 1

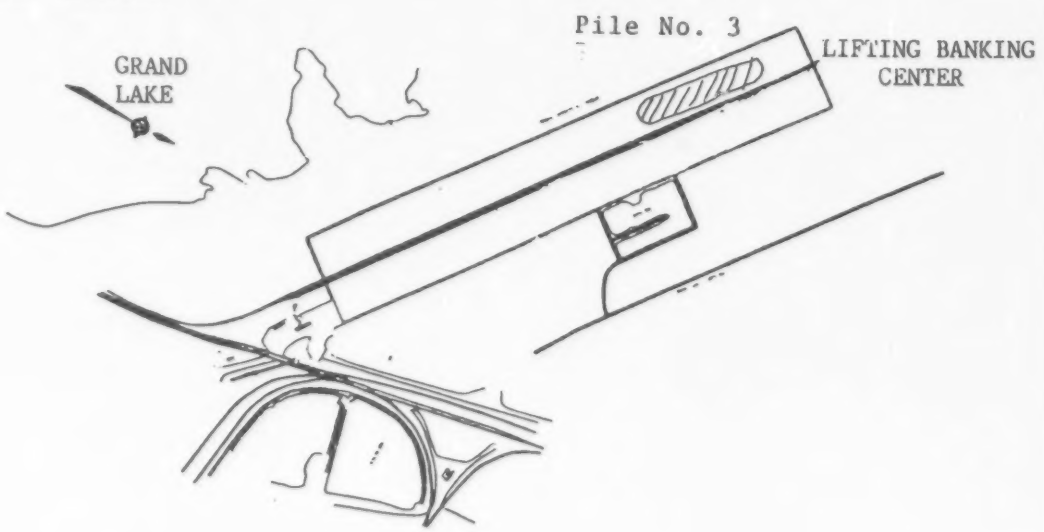
APPENDIX 4

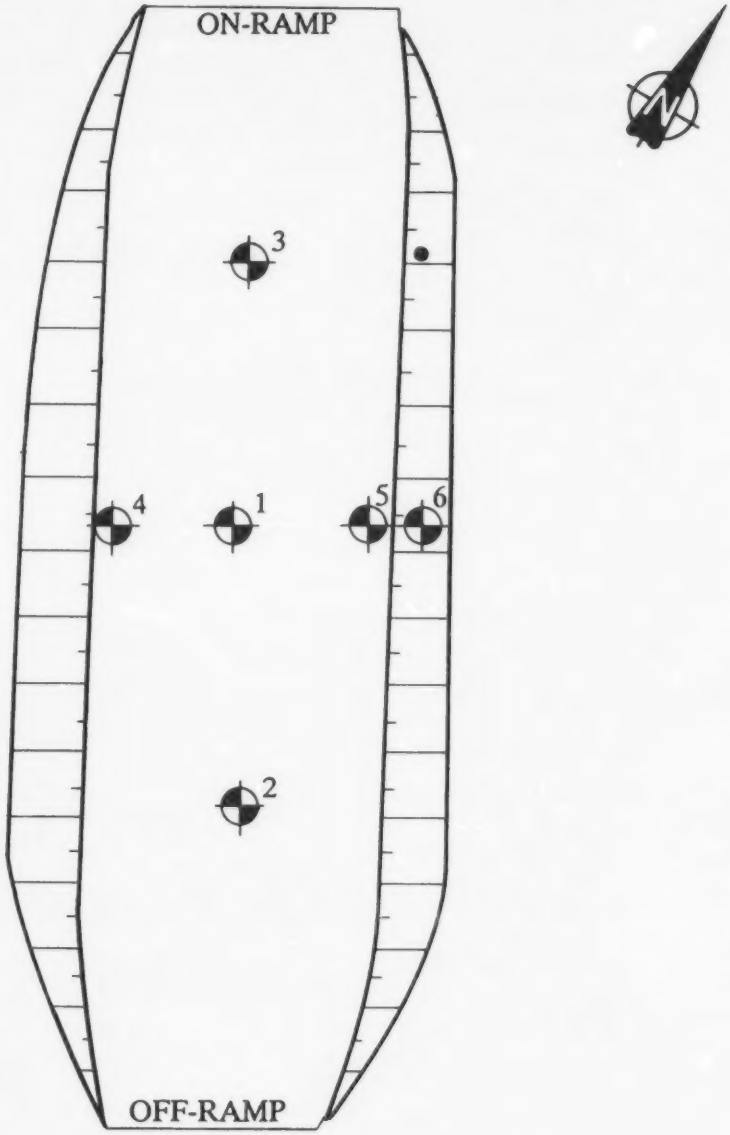
PERTINENT DATA FOR PILE 3
NO. 77 MET BANK OPERATIONAL PERIOD:
MARCH 1990

LOCATION PLAN

KEY PLAN

SCALE 1:10,000





NOT DRAWN TO SCALE

NOLAN, DAVIS & ASSOCIATES

PILE NO 3
LOCATION / NUMBERING OF PIEZOMETERS

STOCKPILE HYDROLOGY STUDY
#77 MET BANK March 1990

Printed 91-01-15

DEPTH IN METERS FROM TOP OF PVC PIPE
(ACTUAL PIEZOMETER READINGS)

DATE	TIME	HOLE # 1	HOLE # 4	HOLE # 5	HOLE # 3	HOLE # 2	HOLE # 6
Depth	meters->	7.20	7.31	7.2[illegible]	6.24	6.18	3.55
90-03-06	07:00	DRY	DRY	DRY	DRY	DRY	
90-03-07	03:00	DRY	DRY	DRY	DRY	DRY	DRY
90-03-08	02:45	DRY	DRY	DRY	DRY	DRY	DRY
90-03-09	02:05	DRY	DRY	DRY	DRY	DRY	DRY
90-03-10	12:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-11	15:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-12	12:50	DRY	DRY	DRY	DRY	DRY	DRY
90-03-13	12:37	DRY	DRY	DRY	DRY	DRY	DRY
90-03-14	12:15	DRY	DRY	DRY	DRY	DRY	DRY
90-03-15	12:40	DRY	DRY	DRY	DRY	DRY	DRY
90-03-16	01:45	DRY	DRY	DRY	DRY	DRY	DRY
90-03-17	14:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-18	16:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-19	15:15	DRY	DRY	DRY	DRY	DRY	DRY
90-03-20	15:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-21	15:40	DRY	DRY	DRY.	DRY	DRY	DRY
90-03-22	13:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-23	12:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-24	02:00	DRY	DRY	DRY	DRY	DRY	DRY
90-03-25	11:15	DRY	DRY	DRY	DRY	DRY	DRY
90-03-26	15:50	DRY	DRY	DRY	DRY	DRY	DRY
90-03-27	15:30	DRY	DRY	DRY	DRY	DRY	DRY
90-03-28	12:00	DRY	DRY	DRY	DRY	DRY	DRY
90-03-30	13:00	DRY	DRY	DRY	DRY	DRY	DRY
90-03-31	11:45	DRY	DRY	DRY	DRY	DRY	DRY
90-04-01	18:00	DRY	DRY	DRY	DRY	DRY	DRY

Thermocouple Readings in degrees Celcius

HOLE #1	HOLE #4					HOLE #3					
0	0	1.52	3.05	4.57	6.10	0	1.52	3.05	4.57	6.10	<-- Height of Thermocouple above base (meters)
	7.31	5.79	4.26	2.74	1.21	6.24	4.72	3.19	1.67	0.14	<-- Distance below surface
0	0	10	6	2	5	5	10	11	11	-8	
0	0	10	6	2	5	1	6	7	7	-2	
0	0	10	6	2	6	1	6	8	7	2	
0	0	10	5	2	5	1	6	8	7	2	
0	0	10	5	2	5	1	5	8	7	-1	
0	0	10	6	2	5	1	6	8	7	0	
0	0	10	5	2	5	1	6	8	7	0	
0	0	10	6	2	5	0	5	8	7	-1	
0	0	9	4	2	4	1	6	8	8	-1	
0	1	9	5	2	4	0	4	7	6	2	
0	1	10	6	3	5	1	5		7	1	
0	1	10	5	2	4	0	4	7	6	0	
0	1	10	6	3	4	0	4	7	6	3	
0	1	10	6	3	4	0	4	7	6	4	
0	2	10	6	3	4	1	4	7	6	4	
1	2	10	6	3	4	1	4	8	6	1	
0	2	10	6	3	4	0	4	7	6	0	
1	2	10	6	3	4	0	4	7	6	1	
1	4	11	7	4	4	2	6	9	8	1	
1	3	10	7	4	5	1	4	8	7	0	
2	4	11	7	4	5	2	4	8	7	0	
1	4	11	7	4	5	2	4	8	7	0	
2	4	11	7	4	5	2	4	8	7	0	
2	4	10	7	4	4	2	4	8	6	0	
3	4	10	7	4	5	2	4	8	7	0	
2	4	11	8	4	5	2	4	8	7	1	

Moisture content of split spoon samples

	Hole # 1		Hole # 4		Hole # 5		Hole # 3		Hole # 2	
	Depth	% moist	Depth	% moist	Depth	% moist	Depth	% moist	Depth	% moist
SA-1	0 - 2	5.29	0 - 2	5.56	0 - 2	2.44	0 - 2	5.41	0 - 2	6.48
SA-2	2'6"-4'6"	6.47	5'-7'	8.47	5'-7'	3.66	5'-7'	5.40	5'-7'	5.18
SA-3	5'-7'	5.86	10'-12'	7.37	10'-12'	4.70	10'-12'	7.70	10'-12'	7.24
SA-4	7'-9'	6.96	15'-17'	5.63	15'-17'	6.24	15'-17'	10.98	15'-17'	4.34
SA-5	10'-12'	7.15	20'-22'	9.84	20'-22'	7.01	20'-22'	8.77		
SA-6	13'6"-15'	7.31	21'6"-23'6"	5.22						
SA-7	15'-17'	5.51								
SA-8	17'6"-19'6"	6.65								
SA-9	20'-22'	4.96								
SA-10	22'-23'	6.60								

(Courtesy CBDC)

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-1MAR
VICTORIA JUNCTION PREPARATION PLANT	PILE #3 - #7 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 03/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▦

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0	☒	2					1.0
2.0	☒	3					2.0
	☒	4					
3.0	☒	5					3.0
4.0	☒	6					4.0
	☒	7					
5.0	☒	8					5.0
6.0	☒	9					6.0
7.0	☒	10		31/2.5D			7.0
			END OF BOREHOLE AT 7.09m. AT TOP OF ASPHALT. ELEVATION				
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 7.1 m	COMPLETE 03/05/90	
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-2MAR
VICTORIA JUNCTION PREPARATION PLANT	PILE #3 - #7? MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 03/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▥

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	■ RECOVERY ■ 20 40 60 80 / ● N-VALUE ● 20 40 60 80 / PLASTIC M.C LIQUID 20 40 60 80	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0	☒	6					7.0
8.0			END OF BOREHOLE AT 7.32m. AT TOP OF ASPHALT. ELEVATION				8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 7.3 m	COMPLETE 03/05/90
	LOGGED BY O.R. N.B	DWG NO.1
		Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-3MAR
VICTORIA JUNCTION PREPARATION PLANT	PILE #3 - #7 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 03/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ☒ SPLIT SPOON

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0							6.0
7.0	☒	5	END OF BOREHOLE AT 7.01m. AT TOP OF ASPHALT. ELEVATION				7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED
Halifax, Nova Scotia

COMPLETION DEPTH 7.0 m		COMPLETE 03/05/90
LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-4MAR
VICTORIA JUNCTION PREPARATION PLANT	PILE #3 - #77 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 03/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ◪ ☒ SPLIT SPOON ☰ ▯ ▯

SOIL/ROCK DESCRIPTION

■ RECOVERY ■ 20 40 60 80
● N-VALUE ● 20 40 60 80
PLASTIC M.C LIQUID 20 40 60 80

USC

PIEZOMETER INSTALLATION

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.
1.0			
2.0	☒	2	
3.0	☒	3	
4.0			
5.0	☒	4	
6.0	☒	5	END OF BOREHOLE AT 6.25m. AT TOP OF ASPHALT. ELEVATION
7.0			
8.0			
9.0			
10.0			
11.0			
12.0			
13.0			

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 6.3 m	COMPLETE 03/05/90
	LOGGED BY O.R. N.B	DWG NO.1
		Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-5MAR
VICTORIA JUNCTION PREPARATION PLANT	PILE #3 - #77 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 03/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ◪ ☒ SPLIT SPOON ☰ ▯ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0			END OF BOREHOLE AT 6.10m. AT TOP OF ASPHALT. ELEVATION				6.0
7.0							7.0
8.0							8.0
9.0							9.0
10.0							10.0
11.0							11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 6.1 m	COMPLETE 03/05/90	
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

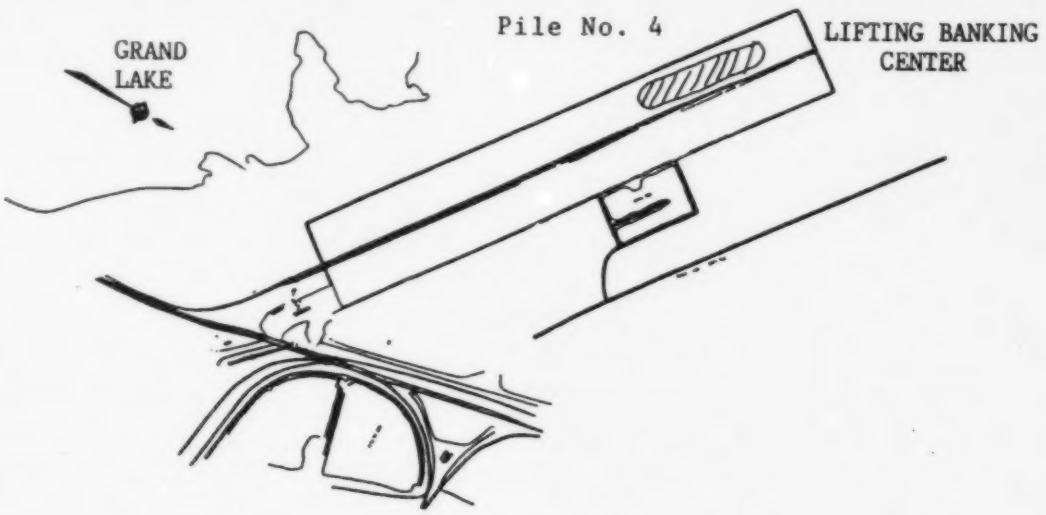
APPENDIX 5

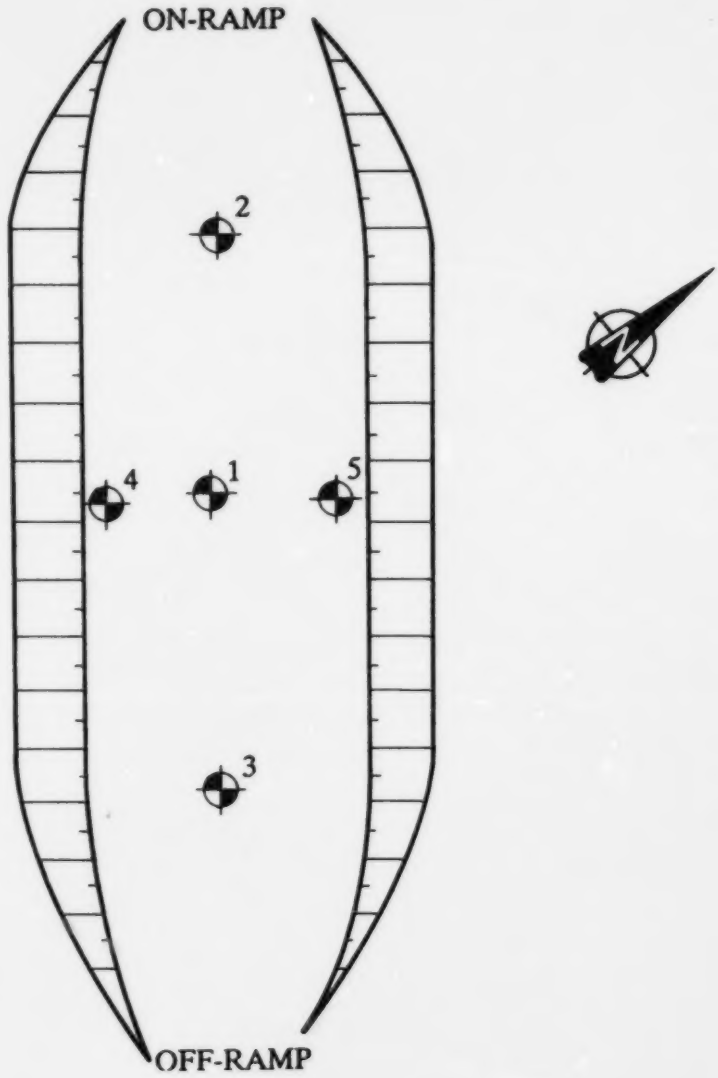
PERTINENT DATA FOR PILE NO. 4
NO. 74 MET BANK OPERATIONAL PERIOD:
JULY TO DECEMBER 1990

LOCATION PLAN

KEY PLAN

SCALE 1:10,000





NOT DRAWN TO SCALE

NOLAN, DAVIS & ASSOCIATES

PILE NO. 4
LOCATION / NUMBERING OF PIEZOMETERS

STOCKPILE HYDROLOGY STUDY
#74 MET BANK July - December 1990

Printed 91-01-15

		DEPTH IN METERS FROM TOP OF PVC PIPE (ACTUAL PIEZOMETER READINGS)					Thermocouple Readings in degrees Celcius				
		HOLE # 3	HOLE # 1	HOLE # 4	HOLE # 5	HOLE # 2	HOLE # 1				
DATE	TIME						0	1.52	3.05	4.57	6.10 <-- Height of Thermocouple above base meters
Depth meters->		-10.91	-12.65	-12.75	-12.34	-11.50	12.65	11.13	9.60	8.08	6.55 <-- Distance below surface
90-07-12	12:00	DRY	DRY	DRY	DRY	-11.201	9	11	11	11	12
90-07-13	12:00	DRY	DRY	DRY	DRY	-11.148	9	11	11	11	12
90-07-16	14:00	DRY	DRY	DRY	DRY	-11.232	8	11	11	11	11
90-07-17	14:05	DRY	DRY	DRY	DRY	-11.232	9	11	11	11	12
90-07-18	14:00	DRY	DRY	DRY	DRY	-11.240	9	11	11	11	12
90-07-19	13:25	DRY	DRY	DRY	DRY	-11.247	9	11	11	11	12
90-07-23	13:25	DRY	DRY	DRY	DRY	-11.293	9	11	11	11	11
90-07-24	14:15	DRY	DRY	DRY	DRY	-11.300	9	11	11	11	12
90-07-25	12:50	DRY	DRY	DRY	DRY	-11.316	9	11	11	11	12
90-07-26	12:50	DRY	DRY	DRY	DRY	-11.308	9	11	11	11	12
90-07-27	12:50	DRY	DRY	DRY	DRY	-11.331	9	11	11	11	12
90-07-30	15:35	DRY	DRY	DRY	DRY	-11.370	9	11	11	11	12
90-07-31	14:08	DRY	DRY	DRY	DRY	-11.300	8	10	10	10	11
90-08-01	17:00	DRY	DRY	DRY	DRY	-11.360	9	10	10	10	11
90-08-02	08:21	DRY	DRY	DRY	DRY	-11.390	8	10	10	10	11
90-08-02	13:27	DRY	DRY	DRY	DRY	-11.425	9	11	11	11	12
90-08-02	20:30	DRY	DRY	DRY	DRY	-11.400	8	10	10	10	11
90-08-03	08:11	DRY	DRY	DRY	DRY	-11.395	8	10	10	10	11
90-08-06	15:00	DRY	DRY	DRY	DRY	-11.415	Not Determined				
90-08-07	15:20	DRY	DRY	DRY	DRY	-11.430	9	11	11	11	12
90-08-08	15:40	DRY	DRY	DRY	DRY	-11.439	9	11	11	11	12
90-08-09	15:30	DRY	DRY	DRY	DRY	-11.445	9	11	11	11	12
90-08-10	14:45	DRY	DRY	DRY	DRY	-11.467	9	11	11	11	12
90-08-13	14:20	DRY	DRY	DRY	DRY	-11.464	9	11	11	11	12
90-08-14	13:50	DRY	DRY	DRY	DRY	-11.464	9	11	11	10	12
90-08-15	12:00	DRY	DRY	DRY	DRY	-11.476	8	10	10	11	11
90-08-16	12:00	DRY	DRY	DRY	DRY	-11.483	10	11	12	11	12
90-08-17	12:00	DRY	DRY	DRY	DRY	-11.483	9	11	11	11	12
90-09-24	12:00	DRY	DRY	DRY	DRY	DRY	Not Determined				
90-09-27	12:00	DRY	DRY	DRY	DRY	DRY					
90-10-12	12:00	DRY	DRY	DRY	DRY	DRY	7	10	10	9	8
90-10-23	12:00	DRY	DRY	DRY	DRY	DRY	7	10	10	9	11
90-11-02	12:00	DRY	DRY	DRY	DRY	DRY	8	10	10	10	11
90-11-20	12:00	DRY	DRY	DRY	Plugged	DRY	Instrument not working				

Moisture content of split spoon samples

Depth feet	Hole # 3	Hole # 1	Hole # 4	Hole # 5	Hole # 2
0 - 2	6.54	9.77	6.21	6.19	6.14
5 - 7	5.86	7.27	7.54	6.30	6.22
10 - 12	7.45	8.33	7.09	9.45	Bottle Broken
15 - 17	7.75	7.93	7.53	7.81	7.53
20 - 22	7.19	7.45	6.67	8.54	7.89
25 - 27	7.11	5.70	7.81	9.26	7.25
30 - 32	8.89	7.87	7.83	8.35	9.21
35 - 37	8.97	8.02	9.28	8.93	11.54
40 - 42	12.66	16.18	11.15		

(Courtesy CBDC)

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-1JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #4 - #74 WET BANK	Project No: 389-089
LONGYEAR DRILLING	START DATE: 07/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▥

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
8.0	☒	6					8.0
9.0							9.0
10.0	☒	7					10.0
11.0	☒	8					11.0
12.0	☒	9					12.0
13.0			END OF BOREHOLE AT 12.6m. AT TOP OF ASPHALT. ELEVATION				13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 12.7 m	COMPLETE 07/05/90	
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-2JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #4 - #74 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 07/05/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▥

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
8.0	☒	6					8.0
9.0							9.0
10.0	☒	7					10.0
11.0	☒	8					11.0
12.0	☒	9					12.0
13.0			END OF BOREHOLE AT 12.5m. AT TOP OF ASPHALT. ELEVATION				13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 12.5 m	COMPLETE 07/07/90	
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-3JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #4 - #74 MET BANK	Project No: S89-088
LONGYEAR DRILLING	START DATE: 07/07/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ☒ SPLIT SPOON ▤ ▥ ▮

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
8.0	☒	6					8.0
9.0	☒	7					9.0
10.0							10.0
11.0	☒	8					11.0
12.0	☒	9					12.0
13.0			END OF BOREHOLE AT 12.65m. AT TOP OF ASPHALT. ELEVATION				13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 12.7 m	COMPLETE 07/07/90
	LOGGED BY O.R. N.B	DWG NO.1
		Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-4JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #4 - #74 MET BANK	Project No: S89-089
LONGYEAR DRILLING	START DATE: 07/07/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ▨ ▩ SPLIT SPOON ▤ ▥ ▥

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY / N-VALUE / PLASTIC M.C LIQUID (20 40 60 80)	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	▩	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	▩	2					2.0
3.0	▩	3					3.0
4.0							4.0
5.0	▩	4					5.0
6.0	▩	5					6.0
7.0							7.0
8.0	▩	6					8.0
9.0	▩	7					9.0
10.0							10.0
11.0	▩	8					11.0
	▩	9	END OF BOREHOLE AT 11.53m. AT TOP OF ASPHALT. ELEVATION				
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 11.6 m		COMPLETE 07/07/90
	LOGGED BY O.R. N.B	DWG NO.1	Page 1 of 1

CAPE BRETON DEVELOPMENT CORPORATION	COAL STOCKPILE HYDROLOGY STUDY	BOREHOLE No. 90-5JULY
VICTORIA JUNCTION PREPARATION PLANT	PILE #4 - #74 MET BANK	Project No: 389-080
LONGYEAR DRILLING	START DATE: 07/07/90 -	ELEVATION 0.00 (m)

SAMPLE TYPE ■ ◪ ☒ SPLIT SPOON ▤ ◫ ◧

DEPTH (m)	SAMPLE TYPE	SAMPLE NO	SOIL/ROCK DESCRIPTION	RECOVERY ■ 20 40 60 80 / N-VALUE ◆ 20 40 60 80 / PLASTIC M.C LIQUID 20 40 60 80	USC	PIEZOMETER INSTALLATION	DEPTH (m)
0.0	☒	1	COAL SURFACE ELEVATION COAL: Poorly sorted, fine sand to fine gravel(maximum size of 1-2 cm.), generally compact to dense, black, coal with layers of varying compactness, grain size and moisture.				0.0
1.0							1.0
2.0	☒	2					2.0
3.0	☒	3					3.0
4.0							4.0
5.0	☒	4					5.0
6.0	☒	5					6.0
7.0							7.0
8.0	☒	6					8.0
9.0	☒	7					9.0
10.0							10.0
11.0	☒	8	END OF BOREHOLE AT 10.90m. AT TOP OF ASPHALT. ELEVATION				11.0
12.0							12.0
13.0							13.0

NOLAN, DAVIS & ASSOCIATES (NS) LIMITED Halifax, Nova Scotia	COMPLETION DEPTH 10.9 m	COMPLETE 07/07/90
	LOGGED BY O.R. N.B	DWG NO.1 / Page 1 of 1

MAPS
NOT
FILMED

CARTES
OMISES